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THE FOUNDRY TRADE JOURNAL IS THE OFFICIAL ORGAN OF THE INSTITUTE OF BRITISH FOUNDRYMEN; THE WELSH ENGINEERS' AND FOUNDERS' ASSOCIATION, AND THE FOUNDRY TRADES EQUIPMENT AND SUPPLIES ASSOCIATION.

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Forthcoming Events.

APRIL 17.
Institution of Engineers and Shipbuilders in Scotland:—Ordinary meeting in Glasgow.

APRIL 21.
Swansea Technical College Metallurgical Society:—Annual meeting at the Technical College.

Institute of British Foundrymen.

APRIL 14.
Newcastle Branch, Junior Section:—Annual general meeting and lecture by F. Allan.
Lancashire Branch:—Annual meeting at Manchester.
Lancashire Branch, Junior Section:—Annual general meeting at Manchester. "Some Observations on Metallurgical Practice in the U.S.A." Paper by C. Brereton.

APRIL 19.
Birmingham, Coventry and West Midlands Branch:—Annual meeting at Birmingham.

APRIL 20.
Sheffield Branch:—Ordinary meeting at Sheffield. "Theory and Practice." Paper by J. Shaw.
Middlesbrough Branch:—Annual meeting at Cleveland Technical Institute.

The Leicester Conference.

We suppose that posterity will label the 1928 Institute of British Foundrymen Convention the Leicester Conference, but really this is too narrow an appellation, because many centres in the East Midlands are contributing handsomely to its already assured success. Arrangements are well advanced, and if the showman's "*greatest*" still retains its pull with the public, as undoubtedly it does, then its organisers can boast of their ability to show visitors several plants carrying this superlative. Leys Malleable Castings Company, Limited, is the largest malleable foundry in Europe. The Stanton Ironworks, Limited, is the largest producer from a tonnage point of view of iron castings in Great Britain, whilst the Rolls-Royce concern can unhesitatingly be accorded the slogan, "The builders of the world's best motor car."

Possibly the other firms who are so kindly opening their works for inspection could also lay claim to special recognition in this American sort of way, but it can be asserted quite definitely that they are recognised as having achieved world-wide reputations for quality and service. The Bell Foundry, the Brush Company, and Herbert Morris, Limited, all of Loughborough, constitute enterprises which justly command respect and admiration amongst British engineering enterprises.

The special conditions of railway foundry work will be seen at its best at the L.M.S. Derby works, and for the first time for many years the works of patternmaking machinery construction, that of Wadkin & Company, of Leicester, is available for inspection.

Socially this Conference will maintain the high standard now associated with these annual gatherings.

The technical papers have been particularly well chosen, and as printed they form a well-balanced programme. The Belgian Paper especially is unique in character, and presents an aspect of the sand question different from any we have so far encountered.

These important phases which we have reviewed are still insufficient by themselves to make a successful convention. It also requires a record attendance, and, granted normal conditions from now to June, we are rather of opinion that this will happen. Mr. S. H. Russell, the president-elect, and Mr. H. Bunting, the conference secretary, and their associates have undoubtedly created a programme of outstanding interest, and it remains for the foundry industry to benefit from this work by ear-marking the period from June 12 to June 15 for the Leicester Conference.

The New Specification.

We referred last month to the forthcoming B.E.S.A. specification for grey iron. This has now been issued as No. 321, 1928, and it may be obtained from the offices of that Association. Its importance lies primarily in the fact that it gives official national sanction to a number of features that are entirely novel in the testing of cast iron, and for this reason alone it is bound to have a most far-reaching effect.

No attempt is made to specify chemical composition, the maker being therefore left free to select whatever composition will, in his view, best meet the requirements of the mechanical tests. The buyer, moreover, may choose a tensile or a transverse test as he prefers, and he may indeed demand both, although it is generally felt that one will suffice. The tests will normally be made on a separately cast bar. A cast-on bar may, however, be substituted if the buyer should demand it, provided that the design and the moulding so permit. The test bar must be cast in green sand in the case of green-sand castings, and in dry sand for dry-sand and loam castings.

The next important new principle concerns the shape of the bar, which is to be round, varying in diameter with the section of the casting represented. For castings below 0.75 in. the bar is 0.875 in. in diameter (the S bar), and where the section is above 2 in. the bar is 2.2 in. in diameter (the L bar). Intermediate thicknesses between 0.75 in. and 2 in. are represented by the bar 1.2 in. in diameter (the M bar). The L and M bars are cast 21 in. long, and are tested in transverse at 18 in. centres, while the S bar is cast 15 in. long, and tested in transverse at 12-in. centres. In the case of the tensile tests, all three bars are machined to standard B.E.S.A. diameters.

Further points in the specification are the breaking load and deflection in transverse, and the ultimate tensile strength for each bar in each of two grades. In the transverse test, over-size and under-size bars are provided for, the tolerances allowed being 0.1 in above or below the standard size. This margin is one that no founder will find it impossible to meet.

An especially admirable feature of the specification is the appendix. This summarises the testing requirements and gives the standard dimensions and tolerances, and the strength in transverse and tensile for each grade in one and the same table. Metric dimensions are also given throughout. In addition there are curves which enable the user to determine the exact breaking load for each kind of bar, if the bar should not be exactly to size, whether to the specified size or to the one or two twentieths above and below for which figures are given.

We would urge everyone in the industry to familiarise themselves with the new specification, and to see whether their mixtures meet the given requirements. We regard its completion and issue as epoch-making in that it marks a great forward step in the industry, and cannot fail to have profound and far-reaching consequences.

XUM

The Derwent Foundry.

Over 400 Guests at the Annual Dinner at Derby.

Many distinguished guests were present at the annual dinner of the directors, staff and employees of the Derwent Foundry Company (1920), Limited, held at the Assembly Rooms, Derby, over which Mr. V. Jobson, the managing director, presided. There were over 400 people present.

Following the loyal toast, the health of "The Employees" was drunk on the call of Mr. Jobson, who mentioned that, according to custom, he would refer to the progress of the Derwent Foundry, as he considered the employees were just as much entitled to know as were the shareholders of the company. Since July of 1927 several more records had been beaten; in fact, it was becoming quite a habit with the firm to break records. The number of employees had increased by 16 per cent., and the wages paid had also advanced, the advance being about 3½ per cent., while the materials purchased from other firms had increased by 16 per cent. The tonnage produced was a record increase of 23 per cent. The firm's customers shared the benefit of the increased output, for the price of castings from the foundry had been reduced by 1s. 8d. a ton., and the price of their "Qualcast" lawn-mowers had dropped by 8 per cent. Moreover, the profits of the firm had increased as well. He mentioned with appreciation that there had been few industrial disputes in the country, and although business at many firms had been quiet, they, at the Derwent Foundry, had been able to carry on full time with the exception of a slight easing up in the lawn-mower shop during the last three weeks. Even that comparative slackness would not be for long. Their ideal was to make a better article than other people and at a lower price, and they realised that one of the necessary factors was better working conditions. At Derwent Foundry they had the right team spirit, and a team second to none. Results showed they were out to "deliver the goods," and their trade mark was becoming known in every corner of the world.

In responding, Mr. G. H. Smith referred to the good feeling that existed between the firm and the employees; and similar testimony was borne out by Mr. A. Hutchinson, J.P., the general secretary of the National Union of Stove, Grate and Light Metal Workers. He said the fact that in the present days of short time the foundry was working fully, and with increased employees, showed that the management was all right; whilst the fact that not since the war had there been any trouble between the firm and his union, showed that conditions were also all right.

Mr. C. W. Bigg, the assistant managing director, said the pride of the directors in the Derwent Foundry was being more and more justified. The presence of Mr. Hutchinson at that event was, in itself, proof of the friendly relations which they had had with their employees. It was not "shop dressing" either, for co-operation was realised as being an indispensable factor for mutual prosperity.

"The Visitors" was toasted by Mr. F. S. Richardson, sales manager, and Mr. T. Copson, of the Zephyr Carburetter Company, and Mr. A. R. Holland, of the Raleigh Cycle Company, responded.

Capt. R. A. Briggs submitted "The Chairman," a toast that was accorded musical honours. The success of the team spirit at Derwent Foundry was chiefly due to the excellent leadership of Mr. Jobson. There were, he said, two ways of trying to get a job done—force and leadership—and he was glad to see that leadership was the method now being adopted by many firms, as well as at Derwent Foundry.

In acknowledging the compliment, Mr. Jobson said it was easy to lead when he knew he had the backing of everyone in the concern. He was confident that the success of the Derwent Foundry would continue and increase.

An interesting ceremony during the evening was the presentation of mahogany-cased mantel clocks to three employees in recognition of long service with the firm. The recipients were Mr. John Kirk (30 years), Mr. George Hendley (29 years), and Mr. Frank Taylor (26 years). Each had an enthusiastic reception on coming forward to receive his gift.

Correspondence.

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

An Appreciation.

To the Editor of The Foundry Trade Journal.

Sir,—In July last you kindly published an inquiry I sent with reference to nigger pots.

I wish to thank you again for your courtesy, and also all those foundrymen who so kindly communicated with me direct and to whom it has been impossible to reply individually. Above all I most sincerely wish to thank are two members of the Institute of British Foundrymen, viz., Messrs. H. S. and A. E. Clark, of Tottenham, who have been spending a few weeks in our sunny little island. They have given me their unstinted advice, based upon their long and varied experience—Mr. H. Clark particularly, who spent a good deal of his time on a busman's holiday, as he was in and out of my foundry most of the days he was here.

Through my inquiry I also am glad to say I have had the honour to be elected a member of the Institute of British Foundrymen. Thanking you again.

Yours, etc.

The Madeira Supply Co., Ltda.,
Jos. H. Quicke, A.M.I.Mech.E.,
Manager.

Madeira.
March 21, 1928.

Institute of British Foundrymen.

Annual Meeting of the Lancashire Branch.

The annual general business meeting and election of officers of the Lancashire Branch of the Institute of British Foundrymen will take place on Saturday, April 14, at the College of Technology, Sackville Street, Manchester, and is to commence at 3 p.m. prompt.

At 4 p.m. Mr. Jos. Hogg, of Burnley, will open a discussion by means of a Paper of ten minutes' duration on "A Foundry Problem," whilst Mr. Holland, of Manchester, will endeavour to arouse controversy by the reading of a short Paper on "Refractories."

Company Meetin .

Vickers, Limited.—The sixty-first annual meeting of Vickers, Limited, was held on March 29, in London, General the Hon. Sir Herbert A. Lawrence, G.C.B. (the chairman), presiding. The chairman, in the course of his speech, said:—With regard to the balance-sheet, you will agree that the financial position disclosed is exceedingly strong, and it is also important to note that, whereas last year there was a contingent liability in connection with guarantees given by your company amounting to £1,032,612, such liability has now been reduced to £104,151. The strength of our financial position is indicated even more clearly by the consolidated balance-sheet. Land, buildings, machinery, tools and plant of Vickers' own works and of the subsidiary companies in which we hold the whole, or substantially the whole, of the capital total £6,965,353, stock and work-in-progress £2,453,318, and debtors £4,272,567. Investments of the parent company in other companies which are not controlled and investments of the subsidiary companies in various undertakings amount to £4,185,255, all valued at cost or market price, whichever is the lower. Liquid assets, comprising cash at bank, bills receivable and Government securities, total £6,124,509, thus indicating the absolute security of our financial position. The total assets of Vickers and its subsidiary companies are £24,001,001. The liabilities amount to £7,079,378, namely:—First mortgage debenture stock, debenture issues of subsidiary companies, share capital of subsidiary companies (held outside group), creditors and credit balances, final preference dividend, a surplus of £16,921,623, represented as follows:—Capital, £12,468,968; reserve fund, £261,789; contingent and other liabilities, including capital reserve, £2,232,776; surplus as shown in the consolidated balance-sheet (subject to the appropriation of the balance of profit and loss account now to be made), £1,958,090. As mentioned, however, the contingent and other liabilities include a provision for certain liabilities which may have to be met, and the item of £285,729 (shown in the balance-sheet) represents the possible loss on the realisation of certain subsidiary companies. Nothing is included either in the case of Vickers, Limited, or its subsidiaries for goodwill and patents.

Random Shots.

A distinguished Sunday contemporary announced not very long ago that it had presented its musical critic with—I think this was how they described it—"a complete wireless installation of the most up-to-date variety," and that he would in consequence be able to include each week adequate comment on music broadcast during that week. Very nice for the gentleman: but why stop there? Why not, for instance, develop the idea of providing all contributors to the press with accoutrement not merely suitable but superlative? How many motoring correspondents are furnished with Rolls-Royces? How many fashion artists have "carte blanche" to dress in the Rue de la Paix? How many of the glib and graphic society gossips have themselves achieved marriage at a fashionable church? How many critics of poetry have ever written a verse?

* * *

The last instance is perhaps not too well chosen; but no doubt enrolment for an appropriate correspondence course would do something to meet the case.

* * *

Certainly the idea is an attractive one; I must endeavour to see where Marksman comes in. . . . The simplest method might be to persuade some good, kind editor—not of the "F.T.J."—that he is a potential musical critic, and so raise the latest thing in multi-valve self-starting breakdown-proof wireless sets, suitably housed in walnut or Spanish mahogany at the least. What a pity that "Random Shots" would appear to offer no excuse for anything of the kind . . . and poor Marksman will have to plod along a little longer with three valves and an occasional breakdown.

* * *

Scepticism has been expressed from time to time concerning various ambitious welfare schemes, and especially those connected with the mines. This little story is offered as an explanation for some small part of the said scepticism. One miner busy beneath the shower in the newly-installed pit-head baths complained to another that instead of getting cleaner he seemed to be getting dirtier. His mate regarded him gravely for a minute, scratching his head the while. Then he had an inspiration. "Lad," he said, "tha's still got tha cap on!"

* * *

Cautionary Tales for Ironfounders (with apologies to Mr. Hilaire Belloc).

Charles Augustus, who Used Bad Language.

A doleful tale I now relate
Of Charles Augustus William Wayte,
Who caused his fond Mama much anguish
By using simply *dreadful* language.
His father laughed and said, "I see
A foreman he must clearly be."
Mama indignantly maintained
He must be something more refained.
They put him in a grocer's shop—
But brief indeed was there his stop.
He tried to drive a motor-bus,
But how those dreadful women fuss!
They tried him as a railway porter,
But *that* idea did not hold water.
He gained a name for losing jobs—
People, you know, are dreadful snobs.
No offers now would come his way,
He moped about at home all day.
Listless and languid, peaked and pale,
The only thing that did not fail,
His flow of words. To bed he took:
His language would have filled a book.
A corpse at last, they buried him
With many a dismal, doleful hymn.
But even that most hallowed air
Seemed strange and spicy words to bear. . . .
"This trouble you would ne'er have had,"
His father said, "if of the lad
You'd made a foreman—but, alack,
It is too late to bring him back!"

Marksman.

Nickel in Cast Iron.*

By Arthur B. Everest, Ph.D., B.Sc.

Introduction.

Until within the last few years cast iron has been regarded by the engineer as a material suitable for his use, principally on account of its comparative cheapness, together with its ease of casting and of machining. Beyond this, however, it was supposed to have few other virtues, and when in the normal development of engineering practice, it was found that the cast iron of the day was proving inadequate to withstand the increasing thermal and mechanical stresses imposed upon it, the engineer showed a tendency to discard it in favour of other materials of better repute. Thus steel was considered as probably the more suitable material for certain parts of heavy internal combustion engines, working at high or fluctuating temperature. The turbine manufacturer was obliged to alter the material and design of the diaphrams, casings, and valve chests of his machine, as steam pressures and temperatures increased. While for other machines, including small internal combustion engines, we find steel substituted for cast iron as liners, and in other parts subjected to abrasion and stress.

To-day, however, metallurgists are realising more and more that cast iron is a material capable of development, possessing besides mechanical strengths greater than any previously associated with this class of metal, valuable properties of resistance to wear and abrasion, and to corrosion and oxidation, properties which for some services render cast iron superior even to steel, and other rivals.

This change in view-point has been brought about as the result of systematic research in cast iron, with the development of engineering practice. This research has led to the improvement in cast iron along two principal lines, namely, by improvement in the technology of melting, handling and heat treatment of the iron; and, secondly, as in the case of steel, by the suitable use of alloying elements. These two lines, however, cannot be considered separately, for in reality they are interdependent. It is not, as will be shown to some extent later in the present paper, an economic proposition to endeavour to improve by alloy additions the quality of metal over whose composition there is little technical control. For the success of alloy cast iron, careful control must be maintained over the iron used as base for the alloy. On the other hand, high-quality cast iron produced as a result of technical control over ordinary or special melting operations, will, it is safe to say, in general, be capable of further improvement by the use of suitable alloy additions. An example of this is seen in Piwowarsky's recent work.[1] Remarkably high-strength figures for cast iron have been obtained by the treatment of cast-iron mixtures by superheating the molten iron, casting it into chill moulds, and subsequently by suitably annealing the castings obtained. By the addition of nickel and chromium to the mixtures, however, still higher strengths, even up to 47.6 tons per sq. in., have been obtained in these experiments.

Among the special elements used as alloy additions for the improvement of cast iron, nickel may to-day claim the first place.

Historical.

It is surprising to find that while nickel was yet a "new" metal, special advantages were recognised in its use as an alloy addition to cast iron, and as long ago as in 1799 a British patent[2] was granted for the manufacture of cast-iron vessels alloyed with from 2.5 to 25 per cent. of nickel; resistance to rusting and corrosion was claimed for these vessels. Again, in 1845, Poole[3] claimed special resistance to oxidation for cast iron with 2 to 10 per cent. of nickel.

Other workers experimented with nickel in cast iron, but no systematic research was made in this field until in 1907 Guillet[4] published the results of his work on nickel in grey and white cast iron. It was shown that nickel acts like silicon in rendering white iron grey; while with higher additions of nickel the cast irons became austentic.

Nickel in Cast Iron.

By Arthur B. Everest, Ph.D., B.Sc.

SUMMARY.

In this Paper, the development of cast iron in general, and of nickel cast iron in particular, is briefly outlined. It is shown that commercial nickel cast irons may be divided in those having high and low nickel contents, those of intermediate content having little or no industrial application. Irons of low nickel content only are dealt with. The advantages obtained by the use of nickel in iron, as shown by the results of previous research work, are set out.

Methods of adding nickel to cast iron are reviewed. As the result of experiments conducted by the author, the influence of nickel on various ordinary foundry mixtures is demonstrated and discussed. It is shown that in a mixture in which the total carbon and silicon contents are correctly balanced, and other elements are present in suitable proportions for a certain casting, the addition of nickel produces little improvement in strength properties, but has a definite advantage in reducing the tendency of the iron to chill.

Nickel is known to act fundamentally as a graphitising agent in cast iron, consequently it would seem reasonable to expect that, in order to obtain the maximum benefit from nickel additions, the other principal graphitising agent in cast iron—namely, silicon—should be lowered. As the result of crucible experiments, it is shown that strength properties far in excess of those normally associated with cast iron are obtained by the replacement of some of the silicon, by nickel in suitable proportion. It is usually found for these purposes that two or three parts of nickel replace one of silicon in ordinary mixtures.

Finally some results are given from work at present in hand, on nickel cast irons made from cupola-melted low-silicon bases, under ordinary foundry conditions. It is shown that such iron may have remarkably good properties.

Further work was published from time to time, principally in France, Germany, America and England, showing that, under given conditions, nickel might usefully be added to cast iron for the improvement of some or all of its properties.

Within the last few years, with the development of cast-iron technology, stimulated on all sides by the war, renewed interest has been taken in the claims of nickel as an alloy addition to cast iron, and this has resulted in the publication of much work, of which the following are some of the principal examples:—

Piwowarsky has worked with nickel additions to ordinary cast irons and found that, under given conditions, nickel produced a definite refining of the grain size of the iron.[5] He found that the addition of one per cent. of nickel gave improved mechanical properties in the iron, but above this amount of nickel added, the strength was reduced[6,7] under the conditions of his tests.

In Great Britain various workers have included nickel in their surveys of the influence of special elements in cast iron. Among these Donaldson[8] & , found that small additions of nickel improved the properties of cast iron. In experiments for growth under the influence of intermittent heating, he found that the nickel iron showed more tendency to grow than did the other special irons tested, but the growth was much less than that obtained with ordinary cast iron under the same conditions. A similar result was obtained by Andrew and Hyman.[10] In the first report of the research with which the present author is connected,[11] the fundamental influence of nickel on iron-carbon and iron-carbon-silicon alloys has been considered.

In France, Galibourg,[12] in a comprehensive review of the use of nickel in cast iron, points out that nickel in iron renders the pearlite sorbitic, it increases the hardness and raises the limit of elasticity, and increases the tensile strength and resistance to impact. He also shows that improved wearing properties are obtained in the iron.

Most work, however, appears to have been done in the United States, where definite improvements in the mechanical strength, machinability and wearing properties of cast iron on the addition of nickel, have been demonstrated by Merica[13], & [14], and Wickenden and Vanick[15] in their very comprehensive work. The economic aspect of nickel additions to cast iron has been considered by Houston[16]; and most recently the use of nickel cast iron for wear resistance in various automobile parts has been the subject of a further Paper by Wickenden[17].

It is not claimed that this review is in any way exhaustive. A more complete review of the work published on nickel in cast iron up to October, 1927, has been made previously by the present author[18].

Study of this work shows that nickel-irons may be divided broadly into two groups, namely, low-nickel alloys in which small additions of nickel, generally under 2 per cent., are added to cast iron, and secondly, high-nickel alloys giving irons in the austenitic ranges. These latter have been developed commercially on account of their non-magnetic[19] and anti-corrosive properties. Between these two groups lie a range of alloys which are martensitic and consequently hard and unmachinable[11].

In the present Paper it is intended to deal with the properties of the first range mentioned above—ordinary cast irons with small additions only of nickel.

From a study of the published work on these low nickel cast irons, it would appear that certain general advantages could be claimed on their behalf. The properties which have been demonstrated for these ordinary low nickel content cast irons may be summarised as follows:—

That (1) nickel reduces the tendency to chill; (2) nickel refines the grain; (3) nickel increases hardness in heavy sections, but as it reduces the tendency to chill, it renders the hardness of a casting more uniform, thereby improving overall machinability; (4) nickel improves the strength properties, and (5) nickel, by refining the grain and the pearlite structure, increases the wear resistance of the iron.

On account of these properties, nickel is finding to-day ever-increasing application as an alloy addition to cast iron, for such parts as automobile engine blocks, cylinder liners, and pistons for giving improved wear and machinability; for forming dies, gear wheels, cams, and other parts where a good wearing, tough, and hard iron is needed, and for numerous other parts where special properties are required of the iron, as for example in electrical resistance grids where mechanical flexibility is of great service, and generally for light section castings where the best properties are required of the iron.

Together with chromium, nickel is finding application as an alloy addition to cast iron for most

* A Paper presented to the European Foundry Congress held in Barcelona on behalf of the Institute of British Foundrymen.

of the above uses and also for grey iron rolls, car wheels and many heavier engineering castings. Nickel-chrome additions to cast iron may prove ultimately of greater importance than simple nickel additions, but in the present Paper it is intended to deal entirely with additions of nickel by itself, and consequently to exclude for the present, consideration of nickel-chrome additions and their influence on cast iron.

Methods of Adding Nickel to Cast Iron.

In making alloy additions to cast iron for the above purposes nickel is added in one or other of various forms, either (*a*) in the cupola, or other melting furnace, being charged into the furnace with the other materials; or, alternatively, it is added (*b*) to the molten metal, in a forehearth or receiver, to the metal as it leaves the furnace, or in the ladle.

Clearly the first method of adding the nickel is applicable only when large tonnages of iron of uniform composition are required, while the second method is the more suitable when smaller weights of alloyed iron are being made up, and when irons of varying composition are required for castings of different types.

The forms of nickel suitable for furnace additions may be summarised as follows:—(*a*) Natural nickel-bearing pig-iron; (*b*) synthetic nickel-bearing pig-iron; (*c*) nickel steel-scrap; (*d*) pig-nickel or ingot nickel-alloys, and (*e*) nickel, or nickel-alloy pellets or shot in suitable containers.

The principal natural nickel bearing pig-iron is Mayari iron. This has a composition (taken on one sample) of TC, 4.23; CC, 2.68; Gr, 1.55; Si, 1.45; Mn, 1.28; S, 0.012; P, 0.078; Ni, 0.89, and Cr, 1.92 per cent.

This iron has been used successfully by some foundrymen, but its application depends more on its chromium content than on the nickel it contains, for undesirably large proportions of this iron would be required in the charge to obtain a nickel content in the finished product even approaching that usually found desirable. More satisfactory results would undoubtedly be obtained by the use of synthetic nickel bearing pig-iron, made up as required, and containing up to 20 per cent. of nickel, or by the use of high-nickel scrap-steel. The author, however, has had no experience in the use of such materials.

Satisfactory results have been obtained by some workers by adding pig-nickel or ingots of nickel-alloys (as, for example, nickel-silicon) to the cupola. Alternatively nickel or nickel-alloy shot or pellets may be added in the furnace in some suitable binder or containers. For this purpose a clay binder has been used, or the shot has been packed into suitable hardwood boxes, or into steel canisters as used for making nickel additions to open hearth steel furnaces.

Some form of container for the shot or pellets is required to hold the nickel until it reaches the melting zone of the furnace, otherwise the fine shot tends to fall through the total depth of the charge, giving an irregular alloy content in the iron produced.

For the addition of nickel to iron for making small or miscellaneous castings, however, it is probably more satisfactory to add the nickel to the iron after it has left the hearth of the furnace. For this purpose various forms of nickel may be used:—(f) Ordinary pure nickel shot or pellets; (g) special fine pure nickel-shot, and (h) nickel-alloy shot, of low melting-point.

The melting-point of pure nickel is 1,452 deg. C., whereas the ordinary foundry temperature of cast iron may be anywhere, for general practice, between 1,250 and 1,480 deg. C., for engineering irons it is generally between 1,300 and 1,400 deg. C. Although pure nickel is reasonably soluble in cast iron, for general purposes it would not appear desirable to add shot nickel of the ordinary size (about 6 to 10 mm. dia.), or there is danger of incomplete solution of the nickel. To avoid this danger pure nickel "fines" are now available as an alloy addition for cast iron. This consists of pure nickel shot of diameter less than 1 mm. Alternatively alloyed shot is used, the alloy having a melting-point comparable to that of the cast iron; this enables rapid solution of the nickel to take place.

Throughout his work to date, the author has used an alloy consisting principally of nickel and silicon, known as "F" shot. This is a proprietary article, and contains about 92 per cent. of nickel. Its melting point is about 200 deg. C. lower than that of pure nickel, and it is fluid at normal casting temperatures for cast iron.

It is generally recognised as undesirable to place the alloy addition in the bottom of a ladle, as unsatisfactory results have been obtained by this method. Good results have been obtained by adding the nickel shot to the stream of metal leaving the furnace, or by sprinkling in into the ladle while the iron is being run in from the furnace or bulk ladle. In each case this method requires for its success a reasonably accurate knowledge of the capacity of the ladle in use.

The amount of nickel that may thus be added without any preheating of the addition, clearly depends on the superheat of the iron, for the alloy addition must itself be heated up and melted by the iron. Using "F" shot, no difficulty has yet been experienced in getting 2 per cent. of nickel into any iron, and no special stirring has been employed. Generally the full addition has been made when the ladle was about half full. The natural circulation of the iron while the ladle was completely filled has provided adequate mixing for obtaining a homogeneous product.

By this method there is apparently no loss of nickel by oxidation; and within the author's experience there is no appreciable loss of fluidity in the iron with additions of nickel up to 2 per cent. This confirms the observations of other workers that nickel in small percentages does not impair the fluidity of cast iron. It is also stated that nickel has little effect on the shrinkage of the iron. (14)

Experiments on Nickel in Cast Iron.

Many of the experiments on which the conclusions set out in the general review given above are based, have been conducted in the United States of America. Some experiments that the author has undertaken in England, using English iron, appear to be of interest in connection with many of these conclusions. An account of some of these experiments is given below.

In the present work the influence of small percentages of nickel generally in the order of 1 or 2 per cent. on various grades of foundry mixtures is described. Except for initial trial experiments on special mixtures, all the iron bases have been melted in an ordinary foundry cupola, from ordinary grades of pig-iron and scrap, so that the development of such mixtures with small additions of nickel is an economic and practical proposition.

The experiments have been restricted to "engineering" cast iron, that is to cast iron of the quality which generally has a combined carbon of about 0.55 per cent. or over in the normal thickness of section of casting, in other words, that it is "pearlitic." It would appear probably from present knowledge that less advantage would be gained by the addition of alloy elements to irons of lower combined-carbon content.

Influence of Nickel on Ordinary Foundry Mixtures.

Experiments have been made on the addition of nickel to various grades of ordinary cast iron, melted under standard foundry conditions. In each case test bars were cast of the iron of composition suitable for normal castings, and of the same with various additions of nickel.

Tests have been conducted on three grades of iron run for engineering castings.

In each case nickel was added as nickel silicon shot. The calculated amount of shot was added as the iron was transferred from a bulk ladle or receiver to a smaller shank of known capacity. Generally a shank of from 1 to 2 cwt. capacity has been used for casting test-bars.

For the mechanical tests on each alloy at least three bars for transverse test have been cast. The bar used was the Institute of British Foundrymen's bar "M"—21 in. long and 1.2 in. dia. This was always cast vertically, and after breaking in transverse test, a tensile test-piece was machined from the lower half of each bar. For studying the variation in hardness, a step casting was employed having steps each 3 in. long by 1½ wide, and one inch, a half, a quarter, and an eighth inch thick; these steps being placed end to end. The whole was poured from the end of the one inch step, a small riser being taken off the extreme end of the ¼ in. step. Other castings for studying chill were made as found convenient.

The Influence of Nickel on a High Grade Automobile Engine Iron.

In this experiment the base iron, as run normally for motor-engine blocks, was retained in a cupola receiver, and each nickel addition was made to fresh metal tapped from the receiver. During the period of the experiment no fresh metal was allowed to enter the receiver, consequently the same base iron was used for each alloy, and the metal was tapped in each case at the same temperature.

The composition of the iron used for this test was:—T.C., 3.30; C.C., 0.60*; Gr., 2.70; Si., 2.08; Mn., 0.96; S., 0.10; P., 0.18 per cent.

Nickel was added to this, giving test bars containing 0., 0.7, 1.12 and 1.84 per cent. of nickel.

Test-castings, having fins of thin section designed to reveal the extent of the tendency of the iron to chill, showed conclusively that the depth of chill was reduced by the addition of nickel. Fractures of fins of equal section from the castings containing 0., 1.12 and 1.84 per cent. of nickel respectively are shown in the photograph, Fig. 1. This reduction in the tendency of the iron to chill has been confirmed in many other experiments; and in this connection it has been shown previously[11] that the addition of nickel will itself turn a white iron grey in a given section of casting.

The mechanical-strength figures, together with the hardness values obtained on the step castings, are summarised in Table I. In this table the percentage of total carbon present as graphite is also given, this figure having an important bearing on the strength properties of the iron.

The drill-hardness figure has been obtained in a standard test, in which a drill of standard steel and ground to constant cutting angles in a jig is forced into the specimen under constant load and at constant speed of revolution. The test drill is ⅜-in. diameter, and pressure on its nose is relieved by the prior drilling of a hole ¼-in. diameter, axial with the path of the test drill. A curve is drawn autographically connecting depth of penetration of the drill with the number of revolutions. The drill-hardness numeral is the number of revolutions of the drill required for 1-in. penetration into the specimen, taken on one or two holes of 1 in. depth drilled by the same drill. The author is indebted to Mr. F. O. Everard, of Messrs. Belliss & Morcom, Limited, Birmingham, for the results obtained in this test.

Table I.—*Mechanical Tests in Nickel Cast Iron.*

Test Bars.	A 20	A 21	A 22	A 23
Nickel content. Per cent.	0	0.699	1.12	1.84
Ratio GC/TC. Per cent.	81.5	81.8	81.4	81.2
Transverse:				
Max. stress. Cwt.	25.36	25.52	26.68	24.58
Deflection. Inch	0.37	0.40	0.43	0.37
Modulus of rupture Tons per sq. in.	33.65	33.87	35.38	32.60
Tensile. Max. stress .. Tons per sq. in. ..	12.74	13.09	13.22	13.25
Brinell hardness:				
1 in. sect.	192	197	199	207
½ in. ,, ...	192	199	210	217
¼ in. ,, ...	229	229	229	235
⅛ in. ,, ...	229	235	235	241

Notes.—The transverse test figures throughout this paper refer to the I.B.F. "M" bar 1.2 in. dia., tested on a span of 18 ins.

The tensile tests were carried out on bars machined to 0.798 in. dia. (½ sq. in. area of cross section) from the bottom end of the transverse test bar. In each case the mechanical test result is the mean of two or three determinations. It should be pointed out that these figures are low for this cast iron because the iron tested is intended for light section castings, and a bar 1.2 in.

* As cast into 1.2 inch diameter bar.

in dia. does not therefore give a true value of the strength of the iron, being of too heavy a section. The hardness values were obtained on the steps of the standard casting as described above.

Consideration of Results.

Consideration of these results shows that on the whole nickel has had no very pronounced influence on the iron. It is interesting to note that the percentage of total carbon that has been graphitised is practically constant. The actual percentage of total carbon fell from 3.34 to 3.28, due no doubt to the diluting effect of the alloy addition.

The tensile-strength of the iron is very slightly progressively raised by the addition of nickel, and the transverse strength, after rising with the first additions of nickel, falls at about 2 per cent. of nickel added.

The drill-hardness of the iron is progressively raised by the nickel additions, but all samples were readily machinable. For comparison it may be stated that a normal hard iron for heavy steam engine cylinders requires eighty revolutions of the drill, while samples have been tested which were still drillable where the drill hardness was over 110.

The steady increase in hardness is seen again in the Brinell tests on the various sections of the step castings. In this case all sections where tested showed a grey fracture.

Microscopic examination of the samples showed that with the first additions of nickel. graphite was coarsened somewhat; with two per cent. of nickel, however, a finer form of graphite was seen.

On etching, all specimens were seen to be pearlitic, with phosphide areas and manganese sulphide crystals evenly distributed. The first addition of nickel produced no appreciable effect on this structure, but the further additions gave a progressively finer structure in the pearlite.

This refining of the pearlite is one of the characteristic effects of nickel, and is undoubtedly the underlying cause of the increases shown in drill and Brinell hardness of the iron, and when associated with a fine graphite form, is shown to result in much improved mechanical properties.

Further Tests.

In a further test nickel was added to iron of a different grade, having the following composition—T.C., 3.61; C.C., 0.85; Gr, 2.76; Si, 1.27; Mn, 0.69; S, 0.12; and P, 0.63 per cent.

Test bars were cast of this iron, and of the same with nickel added to give 0.65 and 0.87 per cent. respectively.

The properties of these bars are given in Table II.

A certain amount of chill at the extreme edge of the ½ in. section in test S20 was eliminated by both nickel additions.

Microscopic examination of the samples showed a large quantity of graphite. The matrix of the iron was largely pearlitic, but in this case the addition of nickel produced no refining of the pearlite form.

Table II.—*Mechanical Properties.*

	S 20	S 21	S 22
Nickel content. Per cent. ..	0	0.65	0.87
Transverse:			
Max. stress. Cwt. ..	21.77	19.06	21.18
Deflection. Inch	0.319	0.280	0.301
Modulus of rupture (Tons/sq. in.)	28.9	25.8	28.2
Tensile strength. Tons/sq. in.	12.14	11.20	12.36
Brinell hardness. 1 in. sect. ..	190	196	202
½ in. ,, ..	205	205	202
¼ in. ,, ..	227	223	228
⅛ in. ,, ..	240	243	245

It is evident from the figures given that nickel in the case of this iron has had little influence on its properties, apart from eliminating a slight tendency to chill on very thin sections. It would seem probable that the high total-carbon present in the iron has been effective in masking the beneficial effects of the alloy addition with regard to strength properties. It is of great interest, however, that in the case of an iron like this of composition unsuitable as a basis of an alloy cast iron, the nickel addition does not appear to have any great deleterious effect.

Table III.—*Mechanical Properties of Nickel Cast Iron.*

	M 0	M 1	M 2	M 3
Nickel content. Per cent.	0	0.5	1.13	2.08
Transverse:				
Max. stress. Cwt. ..	22.16	23.48	21.10	20.84
Deflection. Inch ..	0.258	0.283	0.238	0.242
Modulus of rupture (Tons per sq. in.)	29.4	31.1	28.0	27.6
Tensile strength. Tons per sq. in. ..	15.45	14.99	14.4	13.7
Brinell hardness:				
1 in. sect. ..	217	—	228	231
½ in. ,, ..	228	—	228	228
¼ in. ,, ..	235	—	241	255
⅛ in. ,, ..	269	—	269	262
Drill hardness ..	108	—	137	109

Nickel additions have also been made to an iron as used for cylinders in heavier mechanical-engineering practice. The iron used as the basis of this test showed an analysis:—T.C., 3.40; C.C., 0.80; Gr., 2.60; Si, 1.56; Mn, 0.49; S, 0.099, and P, 0.74 per cent.

To this nickel was added to give the compositions shown in Table III.

Microscopic examination of the iron showed that the graphite form on the first addition of nickel became somewhat coarser, but with subsequent additions the form was rendered finer again. All specimens showed a pearlitic matrix, with the phosphorus constituent evenly distributed.

Again in the case of this iron it is seen that the influence of small additions of nickel on its properties is indefinite. On the whole, there is a tendency for a slight decrease in mechanical strength, and at the same time a slight increase in hardness.

In all these three experiments no appreciable variation in the texture of the test bar fractures was seen with the addition of nickel.

The results of these tests show that nickel has a beneficial influence on ordinary cast iron mixtures in reducing or eliminating any tendency to chill, and at the same time it renders the heavier sections of the castings harder, thereby producing a more uniform overall hardness in castings of variable section.

No definite improvement in mechanical properties has been shown in these tests, however, on the addition of nickel; and again no definite influence on the graphite form has been seen, although one or two per cent. of nickel generally render the pearlite form finer in these particular irons.

Tests on Crucible Melted Iron.

Nickel has been shown to act fundamentally as a graphitising agent in cast iron,[11] and consequently it is reasonable to expect that for the best properties to be obtained from nickel in cast iron, the silicon content should be reduced to compensate for the graphitising influence of the added nickel. Accordingly it was decided to investigate the influence of nickel on low silicon mixtures of cast iron.

As a preliminary to tests carried out on a larger scale on cupola-melted irons, experiments were conducted on mixtures melted in a crucible in an oil-fired furnace at the works of the Midland Motor Cylinder Company, Limited, Smethwick. It is not claimed that tests carried out on such crucible-melted irons are strictly comparable to tests on a cupola-melted base; but they were undertaken to give informations which would indicate suitable compositions of metal for further investigation.

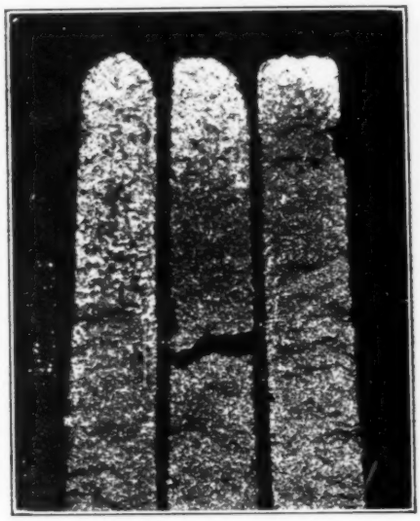

Fig. 1.—Effect of Nickel on Chill.

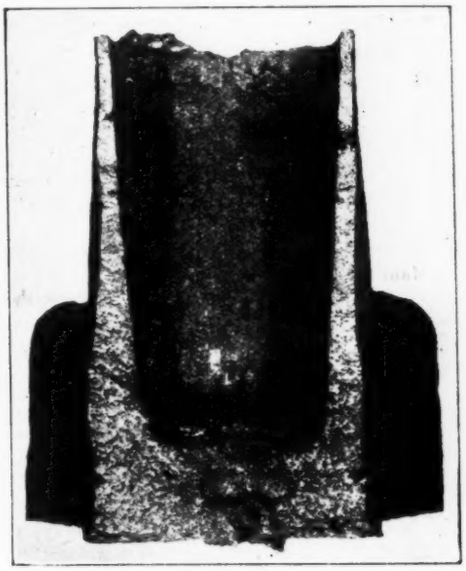

Fig. 2.—Ni, 0 per cent.

Fig. 3. Ni, 2 per cent.

In the following tests about 120 lbs. of iron could be melted at a time. Twenty pounds were used for test castings on the original iron, and two sets of castings, roughly of 50 lbs. weight, were made from the remaining metal, nickel being added as required, directly to the iron in the crucible. A constant pouring temperature of about 1,380 deg. C. was maintained by returning the pot of metal to the furnace for reheating after each set of castings had been made and more nickel added.

In these experiments it was intended to keep the total carbon content of the iron at about 3.2 to 3.3 per cent., phosphorus at 0.2, and silicon initially at 1.2 per cent.; to be modified as found desirable. Manganese and sulphur were maintained constant as far as possible at 0.5 per cent. and 0.06 per cent. respectively.

In a preliminary test small castings were made from metal of the following composition:—

Table IV.—*Composition of Crucible Melted Alloy Castings.*

	X 1	X 2
T.C.	3.178	3.120
C.C.	2.50	1.144
Gr	0.678	1.976
Si	0.905	1.026
Mn	0.49	0.49
S	0.068	0.062
P	0.257	0.255
Ni	Nil	2.055

The mixtures had been calculated to give 3.31 per cent. T.C. and 1.22 per cent. Si. It was found that carbon and silicon were generally lost, as shown above, in mixtures melted in the oil furnace.

The test castings made from the low-silicon base showed white to mottled fractures. Fig. 2 shows the fracture of a casting consisting of a barrel open at one end, and having a wall thickness increasing from about 1/12 in. up to ¼ in. at the closed end of the barrel. This closed end is of thick section (about 1 in.). The corresponding fracture for the alloyed iron (X 2) is shown in Fig. 3. It is seen that the addition of nickel has given a fine and dense grey fracture, showing only 15 mm. of chill at the thin end of the barrel wall.

This change in structure is further shown by the Brinell hardness figures obtained on the step castings.

Table V.—*Brinell Hardness of Step Castings.*

Thickness.	X 1	X 2
1 in.	293	241
½ in.	388	248
¼ in.	352	255
⅛ in.	415	289

Three full crucible tests were carried out on different mixtures of iron, with nickel additions of 1 and 2 per cent.

The analyses of the base irons of these tests are given in Table VI.

Table VI.—*Composition of Crucible Melted Nickel Cast Iron.*

	A 3	A 4	A 5
T.C.	3.25	3.00	3.10
Si	1.05	0.90	1.30
Mn	0.42	0.41	0.56
S	0.07	0.07	0.063
P	0.21	0.026	0.217

The mechanical properties are summarised in Table VII.

In Table VII the tests are arranged in the order of increasing silicon, the approximate analysis of nickel and silicon is given in each case.

The chill figures are taken along the thin section of the barrel of the test piece as shown in Figs. 2 and 3. The influence of nickel in decreasing the chill is clearly seen in each series of tests.

The transverse and tensile tests were carried out as described previously. Without nickel additions these irons are all too hard to be machinable, and no tests were therefore carried out. A consideration of the results of tests on the nickel-alloy cast irons, together with an examination of the fractures of the various test-pieces, shows that nickel prevents chill, even on relatively thin sections, without producing a coarse grain in the heavy sections. Thus nickel appears to maintain the higher strength associated with iron of the low-silicon contents obtained in these tests, and at the same time renders them machinable by eliminating the chill and hard spots inherent in such iron. In this connection it must be remembered that the tensile tests were made on the centre portions of thick bars, 1.2 in. in diameter, and the high values observed are consequently very satisfactory. They represent a very definite advance on the normal irons containing 2.0 per cent. silicon. The Brinell numbers are also considerably higher, while the irons tested are readily machinable except in the thin sections of the step casting. The difference in properties between irons containing 1 and 2 per cent. of nickel is small, and the actual amount of nickel, within these limits, appears to be unimportant provided it is sufficient to prevent chill.

Table VII.—*Mechanical Properties of the Alloys shown in Table VI.*

Bar No.	Analysis. Si.	Ni.	C.C.*	Depth of chill. Inch.	Transverse. Max. stress. Cwt.	Deflection. Inch.	Modulus of rupture. Tons/sq. in.	Tensile strength. Tons/sq. in.	Brinell hardness. 1 in.	½ in.	¼ in.	⅛ in.	Repeated impact. No. of blows.
A 40..	0.9	0	—	All white.	—	—	—	—	326	375	375	430	—
A 41..	0.9	1.0	0.87	Mottled.	31.78	0.319	42.2	18.19	231	332	375	444	—
A 42..	0.9	1.8	0.87	25 mm.	28.72	0.270	38.1	18.76	228	248	241	402	1,143
A 30..	1.04	0	—	50 mm.	—	—	—	—	217	228	248	402	—
A 31..	1.05	1.07	0.80	25 mm.	28.30	0.307	37.6	17.01	217	231	248	302	1,609
A 32..	1.10	2.03	0.73	15 mm.	27.78	0.285	36.9	16.96	231	238	235	255	2,290
A 50..	1.3	0	—	32 mm.	—	—	—	—	217	223	241	430	—
A 51..	1.31	1.03	0.71	16 mm.	26.26	0.322	34.8	15.76	226	226	228	302	1,316
A 52..	1.36	1.93	0.70	12 mm.	27.12	0.306	35.93	17.34	226	238	235	262	1,219

* Combined carbon in bars cast 1.2 in. dia.

The hardness values on varying sections show the various effects of nickel, namely (*a*) the hardening of the completely chilled structure, with increasing nickel,[11] as seen on the ⅛ in. steps of tests A40 and A41; (*b*) the removal of chill by the graphitising influence of nickel, as shown in sections of tests A41 and A42, and in the thinner sections of the other tests, and (*c*) the hardening of the completely graphitised structure as seen in the larger sections of tests A30 and A50.

The repeated impact test was carried out on test-pieces machined from small bars cast ¾ in. in dia., and tested on the Krupp-Stanton testing machine. (A round test bar about 0.6 in. dia. and 6 in. long is supported near the ends, and is hit in the centre by a hammer weighing 4.81 lb. dropped through 1.2 in. The bar is turned through 180 deg. between each blow. Blows are delivered at about sixty per minute till fracture of the bar takes place.)

For purposes of comparison the following approximate figures are given for this test:—Ordinary coarse-grained iron, up to 50 blows; good cylinder iron, about 400 blows; and various special irons, 600 to 1,000 blows.

Undoubtedly the high figures obtained are in part due to the fact that the test bars were machined from crucible-cast bars of small diameter, but these figures are far in excess of others obtained from special mixtures, and are remarkably good for bars in the "as cast" condition.

Considering the properties of each iron, it is found that the irons in series A4 are somewhat too hard for sections under 1 in. thick, with less than 2 per cent. of nickel.

For general purposes the irons in group A3 show better general properties, for although the mechanical strengths are lower than those in the previous tests, nevertheless the irons show a more normal machinability and chill. This iron with 1 per cent. nickel would be suitable for heavier sections (over ½ in.), and with 2 per cent. nickel for lighter sections.

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(*To be continued.*)

I.B.F. Annual Convention at Leicester.

The annual Convention of the Institute of British Foundrymen will be held at Leicester from June 12 to 15, 1928. Arrangements are already well in hand, and in the course of a few weeks all members of the Institute of British Foundrymen will receive full details.

The Papers for the Conference include:— (1) "Steel Castings," by John Howe Hall, given on behalf of the American Foundrymen's Association. (2) "Contraction in Iron Castings," by Maurice Servais (French Exchange Paper). (3) "Malleable Castings," by W. T. Evans and A. E. Peace (Leys Malleable Casting Company, Derby). (4) "Iron Foundry Costing," by W. R. Wintle, of Sheepbridge. (5) "Aluminium Casting Alloys," by G. Mortimer (Wm. Mills & Company, Limited).

The works to be visited include the Stanton Ironworks Company, the British Thomson-Houston Company, Leys Malleable Castings Company, Limited, Herbert Morris, Limited, L.M. & S. Railway Works at Derby, Rolls-Royce, Limited, and a number of other important works.

The social gatherings include a reception by the Mayor of Leicester; excursions to Matlock, Bath and Charnwood Forest, and the annual dinner of the Institute. A very complete programme has been arranged for lady visitors.

A paper on "Locomotive Maintenance" was read by Mr. C. F. Adams before the Junior Institution of Engineers on March 30.

Chilled Iron Rolls.

By Archibald Allison (Sheffield).

INTRODUCTION.

The manufacture of chilled iron rolls is admittedly a difficult technical process, but one in which much information is to be found of great utility in other branches of ferrous metallurgy. This Paper embodies the observations made on over 300 casts under somewhat unusual circumstances, in that the rolls produced were manufactured and used in the same works.

It was thus possible to correlate all the factors, materials employed, methods of production, casting temperature, chemical analysis, depth of chill and actual working life and conditions of each roll. Cast iron possesses unique properties as a material for rolls.

Grain Rolls.

Under the conditions of heating and application of water and scale, iron rolls retain and impart a good surface to material rolled, probably because in grain rolls an aggregate of pearlite with graphite is hard, yet with lubricating properties, and the interruptions of structure provide resistance to expansion and contraction cracking. Also, scale does not bite into the surface so much as in steel, for instance. It may be pointed out that all rolls are pearlitic iron, and for grain rolls to give good service both pearlite and graphite must be fine grained for the above reason, and also on the grounds of mechanical strength. Each roll turner has his preferences, one for a roll which cuts "dry" and another for one which turns "moist," referring to the fineness of grain preferred for his particular work.

Depth of Chill.

Depth of chill is also to some extent a matter of individual choice, and methods of measuring chill depth vary considerably. The limits of chill are (*a*) a good depth to give reasonable life with repeated dressings, and (*b*) not too deep to cause the roll to be mechanically brittle. The life of a roll is a very uncertain quantity on account of the numerous casualties of service conditions. Frosty weather, too rapid heating, cold ends of the rolled piece, stickers, and defective lubrication of necks are among the causes of damage and destruction. It can only be said that since rolls are expensive and somewhat sensitive tools they should be treated with care.

Chilled rolls for hot rolling steel require to have the suitable depth of chill, and should turn up free from pinholes or hard spots, and in service should not develop cracks until after a reasonable service, and even when cracks develop, these should not be so severe that dressing may not render further service possible.

For rolling sections which require gates cutting in the roll, the chill should be hard, and cut smoothly with good finish. For hot rolling thin flats and strips, the chill should be mild to withstand heating conditions, which are more severe than in section rolling.

The appearance of small patches of different colour in the chill is regarded as a symptom of probable future cracking or pinhole development. For cold-rolling, the chill should be hard and free from blemishes, capable of taking a good polish, and the roll should be of good mechanical strength.

Since the above properties are required for the most refractory material—steel—these will probably cover most other requirements for which iron rolls may be used.

It may be pointed out that in either cold-rolling or hot-rolling steel strip, there is a wave action in the chill surface passing round the roll, and hence cracking is longitudinal with the roll and transversely to the direction of rolling, so that the strain upon the properties of the material is very great.

Experiments on the Cupola Melting for Rolls.

A considerable number of experiments were made to cast rolls from cupola metal, with a certain amount of success as regards producing the correct depth of chill and freedom from blemishes. Many rolls rendered satisfactory service, but on the whole it was found that the carbon contents were too high and too irregular.

It is now well understood that cast iron from the cupola cannot be produced regularly with low or controllable carbon, although by employing devices such as a receiver to remove the molten metal from contact with the coke, or very rapid melting, something can be done in this direction. There are also sundry patented arrangements or modifications of the cupola which have yet to be proved, for which many reasonable claims are made.

Whereas these devices might be effective in producing high duty cast iron, it was found in these experiments that as regards chill rolls, however carefully mixed from analysed materials, it is imperative to verify the metal by taking chill tests to obtain accuracy.

Whilst therefore it is possible to produce cast iron from the cupola with fairly-low carbon, this cannot well be done with metal hot enough to wait for the chill test being made before casting.

Some other metallurgical apparatus is called for, some melting furnace or heat machine, which will provide molten cast iron, and keep it hot and unchanged, or with little or controllable oxidation while the exact chill depth is being ascertained.

The electric furnace is indicated by these requirements, but in this country may be considered economically impossible. The coal-fired air furnace is used, but is considered expensive as regards fuel, and the oxidation conditions are not satisfactory. In small and medium-sized foundries the only other possible device is the oil-fired furnace.

Continental Practice.

In some continental foundries where both iron and steel castings are made in the same shop, a very reliable and accurate method of providing iron with definite chill is employed, of melting suitable mixtures of iron in the cupola, and adding a weighed amount of liquid steel made in a Bessemer or Tropenas converter.* This has the great advantage of giving control of the carbon, together with very hot metal.

Cupola Cast Rolls.

There are purposes for which rolls, cast direct from the cupola are serviceable, such as hot rolls for small sections, but the now well-known property of greater mechanical strength associated with lower carbon-contents is additionally confirmed by results obtained with chilled rolls. Cupola-cast rolls are known as hard-chill rolls, and lower-carbon rolls as mild chill rolls, from the degree of ease of turning, and the manner in which the turning roll up.

* Fonderie Moderne, October, 1925

Silicon Content and Chill.

Attempts made to standardise the silicon contents with a definite depth of chill, were not completely satisfactory on account of carbon contents being irregular, but the average of 43 casts giving chill depth 1 $\frac{3}{16}$ in. to 1 $\frac{5}{16}$ in. on the test piece, gave silicon 0.67 per cent., and manganese 0.34 per cent. It was found that rolls made from cupola metal, and hence with carbon 3.3 to 3.6 per cent. fail in service, not so much from lack of mechanical strength as from surface cracking due to contact with hot metal.

Oil Firing Adopted.

While for certain purposes rolls cast from the cupola are satisfactory, for severe usuage and heavy duty it is necessary to produce metal with lower and more regular carbon contents. Accordingly, an oil-fired hearth-furnace was installed and operated close to, and in conjunction with, the cupola: in conjunction, that is to say, so that while the cupola was normally utilised for producing ordinary iron castings, special mixtures could be melted to synchronise with the operations of the oil furnace, as and when required.

OIL-FURNACE MELTING FOR ROLL-MAKING.

The particular oil furnace used, consisted of a rectangular chamber with a somewhat shallow sloping hearth, which will hold 30 cwts of molten metal, but had a convenient melting capacity of 25 cwts. The heavy oil used to heat the furnace was introduced through burners operated by air blast from a fan.

The two oil-burners are fitted at one end, and the waste gases pass through two small vents at the other end, into brick passages over the roof. These chambers contain heater pipes through which the air blast is passed, forming a waste heat regenerative system. By this means, the temperature of the air is raised to 230 deg. C. at the middle of the heat, and increases to 260 deg. or over toward the end of the heat.

The control is effected by means of a water gauge on each blast pipe, oil supply and air pressure being regulated as required. The particular furnace is also fitted with a hopper or pouring spout, to enable liquid iron to be charged at will.

The tapping spout is double, so that in case of trouble with one hole, or for continuous working with successive heats, there is a reserve tapping hole.

It was thus possible, if a heat was tapped out and considered too cold, to pour it back for further heating.

The main purpose of the oil-fired furnace was to utilise the property of liquid cast iron of dissolving mild steel, and thus to reduce the carbon contents, and full advantage was taken of this.

Basic Metal.

In commencing a series of melts, known mixtures containing heavy scrap and pig-iron were charged cold and melted. Chill tests were taken from the bath by means of a small ladle, and the metal suitably corrected according to the ascertained depth of chill. For subsequent heats, mild steel was charged on the hearth and liquid iron from the cupola poured in when the steel had attained the temperature of the furnace. It was found that in half an hour, or sometimes less, the bath recovered a suitable heat after dissolving the steel. It will be seen, therefore, that the oil furnace may be worked as a separate unit for melting cold metal, or for part melting and part mixing with cupola metal. It is possible to tap out part of a charge and plug up the spout to retain the rest, but this was generally considered inadvisable, partly from the risk of hard taps, and partly from the uncertainty as to quantity of metal in each portion, which is very important in producing metal for castings of definite weight.

Feeding the Casting.

A further point about joint working of cupola and oil furnace concerns the feeding of the rolls

Chilled Iron Rolls.

By ARCHIBALD ALLISON.

SUMMARY.

The production of chilled iron rolls is reviewed, and methods described of producing rolls with lower carbon contents. Oil furnace melting and various manipulations are described. Conclusions indicated are, that not only is depth of chill a function of total carbon and silicon, but also that graphite precipitation is more gradual with a lower ratio of carbon to silicon. Indications are given of the relation of analysis to chill depth.

Manganese sulphide is considered to be thrown out of solution in the molten iron between temperatures of 1350 and 1250 deg. C. The limits of carbon contents for chilled rolls for various service conditions are indicated. The effect of chill depth upon length of service, and also the cause of blemishes are considered. Suggestions for standardisation are put forward.

when cast. To avoid contraction cavities it is the practice, after casting, to keep the top open by poking with a rod, and introducing small quantities of hot iron to follow up the natural contraction. This calls for an additional supply of liquid iron for a period of one or more hours after casting. The cupola working in conjunction is, therefore, a necessity.

Table I illustrates the working of the oil furnace.

Table I.—*Calculated Analyses of the Charges and Analyses of Rolls Cast.*

	C	Si	Mn	S	P
Charged	3.40	0.96	0.59	—	—
Found	3.07	0.68	0.35	0.12	0.28
Charged	3.22	1.62	1.01	—	0.41
Found	2.87	1.03	0.44	0.07	0.44
Charged	3.46	0.96	0.59	—	—
Found	3.17	0.71	0.32	0.12	0.18
Charged	3.46	0.96	0.65	0.13	0.31
Found	3.12	0.66	0.27	—	—

Metallic Losses.

Subsequent working indicated that the oxidation losses were—carbon 7 per cent., silicon 20 per cent. and manganese 45 per cent., varying somewhat according to the working of the air blast and the nature of the material charged; sulphur did not increase, although it is understood that the oil contains 3 per cent., and phosphorus, of course, remained as charged. One feature noticeable is that, whereas it is understood from Siemens and Bessemer practice that manganese oxidises first, then silicon, and then carbon; in this process the oxidation affected all three elements at the same time. Carbon did not always drop so much as expected, from the formation of oil coke. Where the oil flame impinges on the bath, sometimes there is formed—from causes obscure—pieces of hard coke a few pounds in weight, which float away in the slag.

Working Details.

This material was found by analysis to be 99.6 per cent. carbon. The nature and quantity of the slag varied somewhat, the best working coinciding with a small quantity of thin slag. It was only necessary to skim slag out of the furnace when it appeared thick enough to interfere with the heating of the bath, which sometimes occurred through attack on the banks where the ganister mixture was less refractory than usual. Normally, when the complete charge was melted and hot, there was perceptible a slight boil or action in the slag, and this proved to be a good indication that the metal was suitably hot for sampling. A green colour in the small flame emerging from the vents also indicated a suitable heat.

The temperature was observed in every case on tapping, by means of an optical pyrometer focussed on the stream flowing down the tapping spout. The usual reading for satisfactory work was 1,300 deg. C. at least, but occasionally temperatures up to 1,360 deg. C. were recorded. A tapping temperature of 1,280 deg. would indicate the desirability of speed in the subsequent operations.

Actually, this temperature is lower than the true temperature of the metal, as all the readings were taken on the stream close to the tapping hole. Readings taken on the stream where it falls into the ladle give a higher result by 40 deg., and this agrees usually with observations on the surface of the still metal in the ladle.

To carry this point through, it may be said that the temperature of casting was observed on the metal leaving the ladle spout, and the readings were generally 15 deg. lower than the ladle indication.

MATERIALS USED.

The base of the melting stock was old rolls. All mixtures were charged by calculation from the analysis, and generally the proportion employed was about two-thirds old rolls and one-third new iron and corrective alloys, the proportions being varied to suit the calculations. The modifying irons were English or Swedish cold-blast irons, Yorkshire, Derbyshire, Lincolnshire and Continental foundry irons, and East and West Coast hematite irons.

Other materials used were mild steel scrap, hard steel scrap, "stalloy" scrap, ferro-silicon, ferro-manganese, ferro-phosphorus and ferro-titanium. All the materials were used from one standpoint only, that of chemical composition, and it was not found possible to discover any other reason for the employment of any particular metal.

The only modification necessary of this statement is that the "stalloy" was extremely difficult to dissolve in the bath of liquid iron in the oil-furnace, although occasionally used in the cupola with satisfaction.

Although in the form of slabs only $\frac{1}{2}$ in. thick, it required so much longer time to dissolve than much heavier mild steel as to delay operations seriously. This evidently confirms the mutual insolubility of carbon and silicon in iron as found by Hague and Turner, 'Journal I.S.I.," 1910, Vol. 2.

Table II.—*Materials—Used Irons.*

Class.	C.	Si.	Mn.	S.	P.	Cr.	Ti.	V.
Hematite Irons ..	3.97	1.60	1.57	0.060	0.080	0.026	—	—
	3.95	3.11	0.85	—	0.054	Nil	0.10	0.04
	4.48	1.26	0.31	0.026	0.020	—	0.07	Nil
	3.92	0.63	1.13	—	—	—	0.10	Nil
	4.27	0.56	1.53	0.040	0.066	—	—	—
	4.58	0.82	1.70	—	—	—	—	—
	3.70	2.42	1.88	0.048	0.032	—	—	—
	3.83	2.85	0.90	0.043	0.055	—	—	—
	—	1.04	2.26	—	—	—	—	—
	—	0.79	1.39	—	0.053	—	—	—
	3.95	1.66	0.60	0.064	0.021	—	—	—
Foundry Irons ..	3.13	1.05	1.17	0.073	1.00	—	—	—
	3.42	2.88	1.71	0.035	1.13	0.14	0.33	0.12
	—	3.95	1.28	—	1.17	0.04	0.18	0.36
	—	2.11	2.04	—	0.87	—	—	—
	3.56	2.57	1.57	—	1.01	—	0.25	0.18
	—	2.35	0.37	—	1.39	—	—	—
	3.16	2.26	0.55	0.022	1.46	0.04	0.19	0.10
	3.56	3.07	1.17	0.024	0.68	—	—	—
Cold Blast Irons ..	3.39	0.56	0.47	0.18	0.40	—	0.03	Nil
	3.00	0.71	0.66	0.14	0.49	—	—	—
	3.43	0.55	0.63	0.12	0.38	—	—	—
	—	0.48	0.68	0.18	0.41	—	—	—
	3.26	0.58	0.43	0.14	0.29	—	—	—
	3.48	0.63	1.02	0.082	0.42	—	—	—
Swedish Irons ..	3.93	1.12	0.63	0.012	0.100	—	—	—
	4.15	0.87	0.74	0.010	0.100	—	—	—
	—	0.75	0.58	0.009	—	—	—	—
	—	0.90	0.79	0.012	0.097	—	—	—

Table III.—*Various Materials Used.*

	C.	Si.	Mn.	S.	P.
Mild steel scrap ..	0.10	tr.	0.40	0.040	0.040
	0.35	0.10	0.75	0.060	0.060
Hard steel scrap ..	1.25	0.20	0.33	0.020	0.020
"Stalloy" scrap ..	0.05	4.35	0.05	0.018	0.015
Ferro-manganese ..	—	—	80.00	—	—
Ferro-silicon	—	44.00	—	—	—
Ferro-phosphorus ..	—	—	—	—	17.60
	—	—	—	—	21.42

The analysis of the scrap rolls used as the base may be taken as represented in Table IV.

Table IV.—*Composition of Scrap Rolls from Various Sources which were Successful in Practice.*

C	Si	Mn	S	P	C	Si	Mn	S	P
—	0.76	0.21	0.23	—	3.07	0.68	0.35	0.12	0.28
—	0.89	0.33	0.18	0.54	3.16	0.80	0.34	0.16	0.49
3.27	0.79	0.32	0.17	0.51	3.18	0.83	0.37	0.15	0.43
3.30	0.86	0.29	0.17	0.60	3.11	0.74	0.29	—	0.39
3.18	0.86	0.33	0.14	0.57	3.17	0.71	0.32	0.12	0.18
3.22	0.91	0.31	0.18	0.48	3.11	0.87	0.33	0.12	0.25
3.23	0.77	0.29	0.20	0.40	3.27	0.77	0.37	0.16	0.21
3.30	0.87	0.30	0.15	0.34	3.28	0.88	0.32	—	0.42
3.37	0.74	0.34	0.13	0.19	3.02	0.88	0.38	0.17	0.46
3.32	0.65	0.33	0.15	0.26	3.07	0.90	0.38	0.16	0.64
3.14	0.82	0.37	0.13	0.25					

The analyses of irons given are selected as typical out of many actually used. It might be noted that the most useful irons for blending are those with silicon under 1 per cent. and manganese over 1.5 per cent., one with low and one with high phosphorus.

For convenience in disposing of awkward or heavy scrap, to reduce silicon and manganese somewhat, and to obtain materials to facilitate calculations and of uniform analysis, stock melts were sometimes made in the cupola, and after well mixing, cast into pigs, of which the analysis could be relied upon to be regular.

Inherent Properties.

In the earlier experiments some regard was paid to tradition in using a certain proportion of new metal and cold blast iron, but as experience indicated no advantage in service these limitations were discarded. To obtain suitable mixtures it was usually necessary to employ the above proportions of new and old iron, and some advantage is derived from having six ingredients rather than four, say, on account of obtaining a more reliable average from that somewhat variable material, pig-iron.

From what is known concerning titanium and vanadium, these elements appear to be beneficial to cast iron, and many pig-irons contain these elements.

Although ferro-titanium was used occasionally, no definite improvement was noted, probably because the irons already contained some. Rolls were tried for these elements from time to time with the following results:—

No.	*Ti.*	*V.*
288 ...	0.04 ...	0.02
289 ...	0.03 ...	0.05
267 ...	0.04 ...	0.03
262 ...	0.04 ...	0.06

THE CHILL TEST.

However carefully the irons be mixed before melting, owing to variable oxidation in melting, and the necessity of producing rolls with the exact depth of chill required, it is usual, and in fact imperative, to take a chill test-piece. This is done conveniently in the following manner:—A cast-iron slab about 2-in. thick is planed smooth, and is supported on rests so that the under side can be felt by the hand. The top surface is black-leaded and polished, and the slab heated until the temperature, judged by feeling with the hand, approximates to that of the chill mould for the rolls. A mould is rammed, of a vertical taper shape, about $1\frac{1}{4}$ in. thick at the narrow edge in contact with the plate and $1\frac{1}{2}$ in. thick at the upper edge and about 4 in. in depth. A convenient length is 8 in.

It will be seen that by filling this mould from a hand ladle the narrower edge of the casting thus produced in contact with the plate is chilled, and the depth of chill is a relative indication of the chilling properties of the metal. It was found that with iron from the cupola, and hence a carbon content somewhat variable from 3.2 per cent. upwards, the chill test was remarkably steady in two ways.

Cupola Metal Controllable.

It was possible to charge mixtures in the cupola to produce a regular depth of chill, and also the actual depth of chill on the roll was regularly $\frac{1}{8}$ in. to $\frac{3}{16}$ in. less than the chill on the test-piece through the slower cooling of the larger mass, which further calls attention to the relative size of the rolls cast. With lower-carbon metal produced through the hearth furnace it was found that the chill test is much more uncertain from variations in the carbon contents.

Too Low Carbon Gives Variable Chill.

It was found that when the carbon fell below 3.1 per cent. the roll had $\frac{3}{4}$ in. less chill than the test-piece, and with carbon contents of 2.9 per cent. the difference was sometimes as much as $\frac{5}{8}$ in. Therefore a corresponding allowance must be made. That is to say, that in every case it is advisable to aim at somewhat greater depth of chill than required, and add grey iron from the cupola to adjust the metal to the desired extent, allowing for the reduction of depth of chill ultimately given on the rolls cast, according to the estimated percentage of carbon in the metal.

For example, it was desired experimentally to produce rolls of exceptionally mild chill with a total carbon of 2.5 per cent. Whereas in a normal mild chill roll of 3.0 to 3.1 per cent. carbon a chill depth on the test-piece $1\frac{5}{8}$ in. would give about $1\frac{1}{4}$ in. on the roll, with the very mild rolls $1\frac{7}{8}$ in. to 2 in. chill on the test-piece was necessary to give the same depth. Also, it was found necessary to give longer cooling time to the test-piece before stripping from the sand.

With 3.1 per cent. carbon in the metal, seven minutes in the sand before stripping and sprinkling with water to cool, was adequate. With low-carbon metal ten minutes was not always adequate. This was shown by casting two test-pieces, cooling one quickly, and leaving the other till cold. With ten minutes' standing in the sand, and then hastening the cooling by sprink-

ling with water, the result was deeper chill than the normally cooled piece showed.

It would appear that with lower carbon-contents the ejection of the carbon from solution by the dissolved silicon proceeds more slowly, and is not complete at 920 deg. C.

It was found in certain cases that when the chill test-piece of cupola metal was stripped and sprinkled too soon, while the outer layers of the piece above the chill were normally grey, there was in the centre a layer whose fracture indicated chilling. The explanation offered is that the outer layers had cooled normally grey, and the water cooling acting upon the grey outer layers produced a chilling effect on the still sensitive core. A further point was observed with metal for mild rolls, that the length of the piece was a factor in obtaining an accurate test of chill. While a piece 6 in. long was frequently cast, decidedly better results were obtained with pieces 8 in. long, since it was possible to hasten cooling by sprinkling the ends, without causing any false chill effect on the centre portion where the fracture is made for examination.

Checking Test Plate Temperatures.

As to the heat of the chill plate, usually this was judged by feeling with the hand on the under side. As the same operator observed this matter all through these experiments, the same conditions may be granted throughout. At the same time, to ascertain exactly what was the suitable temperature, holes were drilled $\frac{3}{8}$ in. diameter and 1 in. from the surface. A thermometer was inserted, and it was found that a plate considered "too cool" was 34 deg. C. and "too hot" 86 deg. C. "Just right" was 60 deg. C. Chill tests cast on plates "too hot" and "too cool" did show slight differences in depth of chill, but not serious, and insufficient to affect the general conditions.

Another variable is the drop in temperature caused by taking a small quantity of metal in a hand ladle for chill test. The small ladleful cools very rapidly, so that for comparative purposes casting should be done as speedily as possible.

Some investigators have found that hotter metal produces deeper chill, but the present experiments failed to show any appreciable difference, when operating within normal ranges of temperature.

It is true that on a few occasions the chill test was found to indicate a depth of chill considerably greater than subsequent indications justified. This was when the metal was much hotter than usual, and the time of cooling only slightly longer than usual. This false chill was characterised by the upper portion of the piece, which, instead of having a close-grey fracture, had a fracture white, with sharply defined rosettes of graphite. The remedy is, therefore, with very hot metal to make liberal allowance of cooling time before stripping the piece from the sand.

It was found to be imperative to give a thorough stirring to the molten metal to ensure uniformity, since a liquid having a density about eight times that of water is not readily mixed. On occasion, the test taken by small ladle out of the oil furnace was found to be unreliable from this cause, since two further pieces cast as a check at short intervals agreed with each other, but not with the first.

Typical tests such as $1\frac{11}{16}$-in. chill, $1\frac{11}{16}$-in. and $1\frac{3}{4}$-in. at 15 minutes interval, proved the metal definitely. The somewhat shallow bath in the oil furnace was best rabbled with a flat bar, used like an oar, whilst the metal in the ladle was more easily mixed with a square-ended rake.

Considered generally, on the whole the chill test carefully made was a pretty good indication of the actual chill on the roll. In a few cases in which discrepancies were observed it was found that the analysis was a truer guide than the chill test.

The use of the chill test has been advocated by others as a guide to composition and quality of other cast irons than for chilling purposes, and in many cases, side by side with the roll experiments herein recorded, many chill tests were most usefully made in connection with low-silicon iron castings. Especially is the chill test of value in connection with the newer cast irons for heavy duty, in which there is both lower silicon and lower carbon.

CASTING.

Chilled rolls are cast by ascension and centrifugally, the runner entering the mould at the bottom neck and at a tangent, so that the roll barrel is virtually a circular ingot. This is rendered necessary by the importance of having the outer portion as perfect and solid as possible.

In order to produce this result, a trumpet runner is used, the hole being closed with a round iron stopper. There are two small "bleed" holes, which enable small streams of metal to trickle past the stopper, so that when the trumpet is filled with metal and the stopper removed, the full flush of the metal is cushioned somewhat by the quantity already in the runner, and its erosiveness reduced. The trumpet being kept full, small quantities of slag remain on the surface until casting is completed, the metal rising with a rapid rotary motion in the mould, and being permitted to overflow to sweep out any dirt or slag. It was frequently observed that slag which escaped into the trumpet towards the end of pouring could be seen coming from the mould with the overflow metal.

Fig. 1 illustrates the details of the casting arrangements.

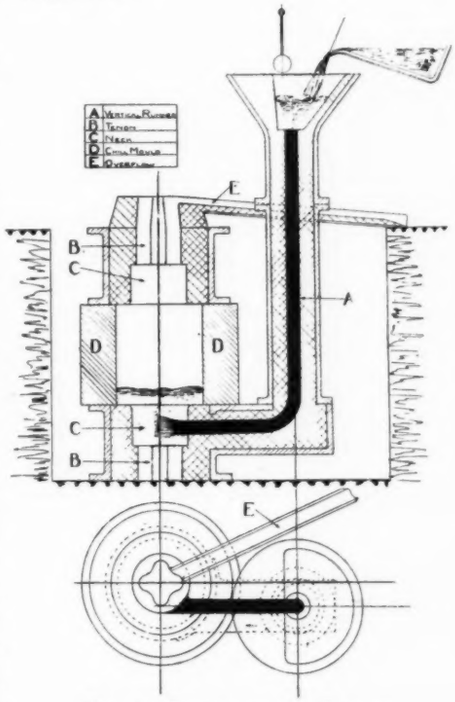

Fig. 1.—Details of the Casting Arrangements.

The blemishes most frequently occurring are small pinholes, which point towards the centre, and occasionally flatter holes which may contain a small globule.

The pinholes were regarded as gas cavities produced by action of the hot metal on thicker spots of the chill mould blacking. While care was taken to black the mould evenly and thinly, the experiment was tried of raising the phosphorus content slightly, on the ground that good rolls frequently contain 0.5 per cent. or over. The rolls then being made ran from 0.30 per cent. to 0.35 per cent. phosphorus, and it was thought that the phosphide eutectic might liquate into any gas cavities without any detriment to the roll surface. Accordingly use was made of phosphoric irons, or of ferro-phosphorus, and the contents raised and rolls cast with 0.45 per cent. to 0.5 per cent.

Some of these rolls appeared to have spots in the chill of a lighter colour, and occasionally holes developed on grinding through a pellet breaking out. In service no particular difference was observed, but it was thought that on the whole it was advisable to reduce the phosphorus somewhat, and work with 0.4 per cent. as the maximum, with the result that as far as turning was concerned the chill surface was improved.

In cast iron it is always necessary to compromise between metallurgical and practical requirements. To obtain evidence with regard to these various points connected with chilled rolls, it is necessary to take many examples over an extended period, since to investigate means destroying a possibly useful roll, by exceedingly heavy machining costs. Attempts to prove the surface spots by taking turnings from the area affected showed no marked difference in phosphorus contents, but these surface markings were not noticeable when the phosphorus content of the metal was below 0.4 per cent. Generally speaking, surface blemishes were found less frequently when the greatest possible care was taken in blacking the chill mould.

The temperature of casting was observed in every case by the same optical pyrometer. While the skilled eye of the foreman is a pretty good judge of heat, the pyrometer was found to be essential in regulating the casting temperature, to hasten if on the cool side and to wait if on the hot side. Some rolls cast as cool at 1,200 deg. were found to give satisfactory service, but on the whole, with a casting temperature of 1,210 deg. or less, the upper end of the roll barrel, at right angles to the working surface where the neck is formed by the sand mould, was frequently studded with holes and pellets. With a casting temperature of 1,260 deg. or over there was found to be some liability to spongy necks and pinholes in the barrel. The suitable range of casting is, therefore, somewhat narrow.

The chill mould itself is required to be massive* in order to prevent distortion of the barrel, either ovalisation or warping, and the thickness of the mould is usually half the diameter of the roll for this reason, as the chilling effect could be produced by a much thinner mould.

Notwithstanding the massive mould and the care taken in heating it, one trouble occurs frequently in the form of ovalisation of the barrel and eccentricity of the chill. No regularity was perceptible: sometimes the larger diameter coincided with deeper chill, sometimes the reverse. Sometimes the chill was "thick and thin," that is, not merely eccentric but thick and thin portions alternating round the circumference.

The only general tendencies noted were that eccentricity and irregularity of chill occurred in rolls of deeper chill, and warping and ovalisation in the lower carbon rolls.

By elimination of such possible causes as unequal heating of the chill mould, and irregular flow of metal, the conclusion was arrived at that rolls of lower carbon and deeper chill have a greater contraction than grayer rolls, and that the lagging of the moulds by burying completely in sand, to promote steady and uniform cooling, is desirable.

(To be continued.)

Algoma Steel Industry.—A year ago the Algoma Steel Corporation had something like $2,000,000 worth of orders on hand; to-day that figure has been increased four-fold. The business is understood to include rail orders amounting to over $4,000,000 placed by the Canadian National and Canadian Pacific Railways, and an additional $1,000,000 from other railways in Canada.

B.S. Tables of Pipe Flanges.—The British Engineering Standards Association has issued Part 1 of the revised Tables of Pipe Flanges (Publication No. 10, 1928), which, with Part 2 (Steam) published in 1926, completes the revision of the 1904 edition. Part 1 comprises the three tables A, B and C, which deal with flanges for pipes, valves and fittings for gas and water. Dimensions are specified for pipes up to 72-in. nominal bore for working water pressures up to 50 lbs., and up to 48-in. nominal bore for working water pressures up to 130 lbs. and 175 lbs. per sq. in. respectively, while the gas-pipe flanges are for working pressures up to 30 lbs. per sq. in. Copies of the tables (No. 10, Part 1—1928) may be obtained from the Publications Dept., British Engineering Standards Association, 28, Victoria Street, London, S.W.1. Price 2s. 2d. each copy, post free.

* Schüz, "Stahl und Eisen," 1923.

XUM

Scottish Moulding Sands.*

By F. Hudson.

The object of this Paper is to accentuate the need for learning more about foundry sands. In Germany and in America one is impressed with the formation of committees to explore and apply this material to the best advantage. In this country foundrymen appear to be a little backward in this respect, but there is little question that in future foundry work the control of moulding sands will be a very important duty to those who wish to keep an eye on profits.

Science, hand in hand with labour, is inscribed upon the seal of the Institute, and it is felt that in those words lies success to any study or investigation upon this question. This inscription, in fact, has been running through the minds of the metallurgical staff of Glenfield & Kennedy ever since this investigation was started in February last year, and although it has obtained something for its labours, yet it has still a long way to go. However, it stated quite clearly that this is not a scientific Paper, but a Paper as practical as it can be, and it is hoped that it will be of some value to founders in general. The best promise for the success of the industry seems to lie in the co-operation of each one of its members with the other, and the author makes a plea at this time for as many members as possible to take up sand testing and study the results they obtain, as well as giving it away for the help of others. The apparatus needed is quite inexpensive.

The Ideal Sand.

Before describing the apparatus used, and the results obtained in the tests on the various supplies of Scotch moulding sands, it may be as well to define an opinion as to *the ideal moulding sand*, in order to gauge the relative merits of each. In this connection the author firmly believes that one sand will never give satisfaction to the foundry trade as a whole, and therefore *the* ideal moulding sand will only exist in the singular for one typical application. Ideal sands must be developed for non-ferrous work, others for cast iron, and still others for steel castings. To get the best results the sands used in these three particular branches of foundry work must be still further sub-divided, according as to whether castings are made in green sand, dry sand, or loam, or whether the sand is used for moulding ornamental stove-plate work or heavy structural parts. In one instance the most looked-for property of an ideal sand is its power for producing a casting with a smooth skin, whilst venting properties rank second in importance. On the other hand, many require a sand having excellent venting properties, but with skin-producing power in the second place.

These remarks clearly suggest that each one will have quite a different conception of those properties which go to make the ideal moulding sand, according to the kind of work produced. However, in the physical properties of the various sands examined, as will be shown later, provision has been made for selecting the sand most suitable to a particular application providing a practical interpretation can be applied to those properties required of the sand for successful casting production. Taking the author's own requirements for grey iron hydraulic engineering castings as a concrete example, an ideal would consist of a sand having excellent bond yet as open as possible consistent with fairly good skin production. In this instance, a sand composed of medium uniform one-grade silica or quartz grains of a spherical or slightly sub-angular form, with each grain coated with the minimum amount of strong bond to give the necessary cohesion, would be required. The efficiency of the sand would greatly depend on the strength of the bond, as the stronger the bond the less would be required to cement the grains together, and the sand would be correspondingly more open. Such an ideal is exemplified in Fig. 1.

The top diagram represents the theoretical way an ideal moulding sand should pack under the rammer. The white circles represent the one-sized quartz grains. Around each grain is the bond represented by the "inlined" portion. The

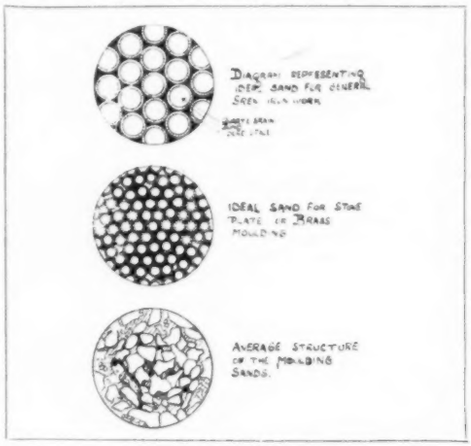

Fig. 1.—Ideal Moulding Sands Diagrammatically Expressed.

black spaces between the grains determine the porosity of the sand. If such a sand could be obtained it would be impossible to ram too hard, but at the same time if it contained excess bond this would be squeezed away from the grains and would block up the pore spaces, and so cause impermeability. This diagram can be said to represent an ideal sand suitable for general grey iron work.

In the middle diagram a similar state of affairs exists, except that the quartz grains are smaller, and although the total area of pore space is the same as in the diagram above, yet such a sand will have less permeability and would be more adapted to brass-foundry work.

In the bottom diagram there is represented the state of affairs which exist in ramming a moulding sand made up of varying-sized grains and carrying excess bond. What pore spaces that are available are completely blocked by the excess bond at the expense of permeability. Unfortunately, it is only too true that this latter example is most typical of the sand used by most foundrymen. It

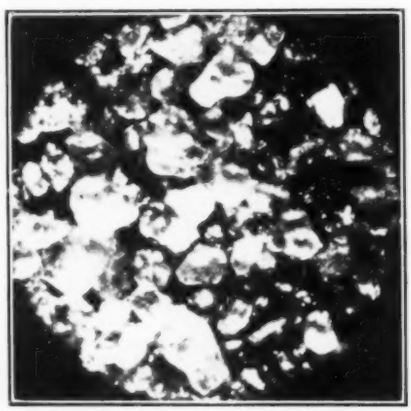

Fig. 2.—Dried Core, made from an Oil-Sand Mixture × 40.

should be clearly understood that there is a large difference between the porosity of a moulding sand and its permeability. Porosity can be stated as the total area of pore spaces over a certain section, whilst permeability is the resistance offered to the passage of gases through the pore spaces.

Fig. 2 is a microphotograph taken at 40 magnifications from a dried core made in sea sand bonded with linseed oil. At the present time this is the nearest practical approach to the expected structure of an ideal moulding sand. It should be noticed that the quartz grains are uniform and nearly all of one size, whilst the sand is open and quite permeable. The bond in this instance is covering the grains so finely as to be not noticeable, yet excellent strength was obtained. Fig. 3 shows the structure of ordinary clay or loam, and although the magnification is exactly the same as in Fig. 2, any sand grain present is entirely obliterated by excess bond. As a result, this material is absolutely impermeable, although admittedly quite strong. It may be of interest, however, to learn that even in the matter of strength, the sea sand, bonded with the oil, was superior to the clay, when both these sands were tested in the dried condition.

Thus the size and quantity of the quartz sand grains which go to form a moulding sand, together with the quantity and distribution of the bond, are of great importance in selecting an ideal sand for use in foundries. As a guide to decide what would constitute an ideal sand for different purposes, Smalley gives an excellent little table in his paper* on moulding sands, and reproduced in Table I, which shows quite clearly in a general way the order of merit of the physical properties required by sands for the casting of various alloys.

Taking the column for cast iron as an example, one notices that the most important first quality of a moulding sand for general purposes is that

Fig. 3.—Ordinary Loam × 40.

of bond, followed by permeability. For light ornamental cast-iron work one would think that the column under the bronze heading would be acceptable as an ideal, as in this instance texture, or skin-producing powers, come first, followed by bond in the second position. Altogether this table can prove an excellent help, provided it is accepted in a general manner.

Table I.—*Requirements of Moulding Sand for Various Alloys.*

Aluminium and its alloys.	Brass.	Bronze.	Cast iron.	Steel.
Bond	Bond	Texture	Bond	Refractoriness.
Texture	Texture	Bond	Permeability	Water content
Water content	Refractoriness	Heat conductivity	Refractoriness	Heat conductivity
Permeability	Longevity	Longevity	Texture	Bond
Heat conductivity	Water content	Permeability	Longevity	Permeability
Longevity	Permeability	Refractoriness	Heat conductivity	Texture
Refractoriness	Heat conductivity	Water content	Water content	Longevity

* A Paper read before the Scottish Branch of the Institute of British Foundrymen, Mr. Longden presiding in the absence of Mr. Thomas Bell through illness. The author is metallurgist to Glenfield and Kennedy, Limited.

* Proceedings of the Institute, page 321, Vol. XVI, 1922-23.

Methods Used in Testing.

The policy followed after much consideration and experimental work has been to instal apparatus for laboratory work and other instruments for practical testing of the sand and actual moulds. At the present time nearly all of the apparatus used by various investigators has failed to give any results whatsoever when applied to actual moulds in the foundry. If research work is done in the laboratory, the practical results cannot be successfully concluded unless one knows exactly what is happening to the sand during the initial preparation and consequent mould manufacture.

As a simple example, an excellent sand found most satisfactory under laboratory tests may turn out hopeless castings, due to more water or harder ramming in the foundry compared with that applied in the laboratory. The use of practical routine control instruments is quite an obvious need to supplement laboratory work, and for the general information of the foreman. Although experimenters have only recently devised instruments for this latter work, yet they are included in this paper to give an idea of future intentions in attempting to obtain control over practical sand and moulding operations. However, except for their description and use, it is not intended to dwell long on this subject, as it lies outside the scope of this paper.

The laboratory apparatus used was that employed by Smalley, as described in his aforementioned paper. This apparatus was selected for two reasons, the first being the fact that his paper includes a series of test results showing the properties of English moulding sands, and a comparison of Scotch sands would prove of interest and value. The second reason was, that the author worked under the direction of Smalley in preparing sand tests with this apparatus, and was quite conversant with it before preparing this present work.

Fig. 4 gives a perspective dimensioned sketch of the laboratory testing apparatus. A is an

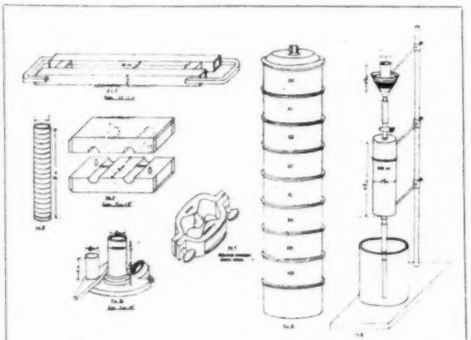

Fig. 4.—Laboratory Sand Testing Apparatus.

ordinary glass tube graduated in inches for doing Fletcher's excellent and informative subsidence test; B is a set of sieves for mechanical grading; C is a core box for obtaining the green-dropping test used to determine the relative bond in green sand. (This box is also used to obtain the transverse test for dry sand work); D is the apparatus used for ramming the green sand permeability test; E is the mould for dry sand tensile test; F is the core box for the dry sand permeability test, and G the aspirator used for drawing air through the different permeability tests and showing in this case a dry sand core in position at the top.

Texture.

For this purpose the sands were put through 120, 100, 90, 80, 60, 40, 30 and 20 mesh sieves, the amount passing each being recorded as a percentage of the total under a heading of mechanical grading. These simple sieve tests give a great deal of information regarding the grain size of the sand and the proportion of clay and silt grades present. At the same time there are many technical objections to this method, two of the more important being the shape of the sieve mesh and the fact that certain sands carry a thick coating of clay around the sand grains, which naturally makes the true grain of the sand larger than it really is, and records less clay present. It would seem that to obtain an accurate result, instead of treating a dried sample, one must treat the sand in boiling water, as even repeated washing with cold water in some sands does not clean the bond from the grains.

Table II.—*Comparison of Sample Treated with Cold and Boiling Water.*

	Treated 10 times with cold water.		Treated with boiling water.	
		Per cent.		Per cent.
Size of meshes measured microscopically in m.m.	Sand Content Clay Content	92.0 8.0	Sand Content Clay Content	84.3 15.7
0.5		5.4		2.6
0.3		2.2		1.3
0.2		28.4		16.4
0.15		42.7		45.9
0.12		5.2		7.5
0.08		4.3		5.9
0.06		0.6		0.8
0.05		1.1		1.5
Smaller than 0.05		1.4		1.8
		0.7		0.6
Weighing loss		92.0		84.3

In Table II is reproduced the results of a German investigation on this question. The large difference between the clay contents of sand treated ten times with cold water and the same sample treated with boiling water is worthy of note. In the present tests all grading was done on 100 grms. dry sample. In confirmation of these results, Fletcher's subsidence test was applied as described in The Foundry Trade Journal, page 389, of November 4, 1926. The method of doing this test is fully described in that article. Its basic features depend on shaking a certain volume of dry sand up with water in a graduated glass tube and timing the fall of sand. It can readily be understood that a fine sand will fall much slower in water than a coarse sand, and that clay due to its colloidal nature will be held in suspension until the sand grains have settled. After the results are plotted on a graph one obtains a very valuable guide to the texture of the sand, the relative amount of bond present, and a sure means for applying a quick test in finding out the location of a questionable sand. Fig. 5 illustrates the glass tube and appearance

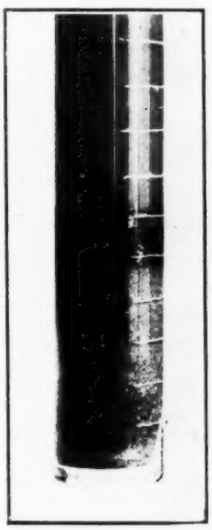

Fig. 5.—Fletcher's Subsidence Test.

of the sand column after completion of the test, showing the coarsest sand grains at the bottom and the clay deposit on the top. In the author's experiments it has been the practice to perform these two tests firsts in examining any sand.

The sand sample is now divided into two portions to determine its suitability for green sand and dry-sand work. The sand is tempered to give 7 per cent. moisture, for green-sand work, and 1 per cent. moisture for dry-sand work. In tempering the sand the practice is to determine the existing moisture content and then adjust the sand either by air drying or by adding water to give the required figure. It is not good practice to drive off the moisture in the sand by heat and then add the required amount of moisture unless the sand is allowed to stand for at least 10 hours, as it was found that the correct properties of the sand did not develop under this time.

Green Sand Testing.

Two tests are made to determine the suitability of a sand for this class of work, the first being

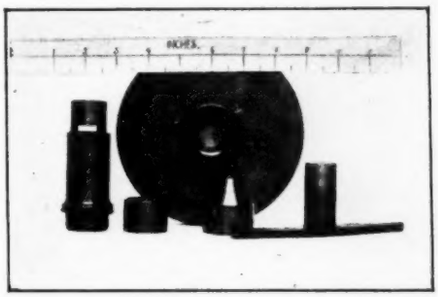

Fig. 6.—Apparatus for Green Dropping Test.

called the green dropping-test, which gives an excellent index of the strength of bond. The sand is rammed up in a skeleton core box on a $\frac{3}{8}$ in. thick glass plate to give a bar of sand 12 in. by 1 in. by 1 in. long. The glass plate projects over the edge of a bench, and the sand is gently pushed over the edge of the plate until the sand collapses. The length remaining (measured from the middle) subtracted for the original length, is recorded as a measure of the bond, the average of at least four tests being taken. The second test is to determine the permeability of the sand. In this case a green-sand core 3 in. long by 1 in. diameter is rammed up in the apparatus, as shown in Fig. 6. Figs. 7, 8 and 9 indicate progressive stages in obtaining the core free from ramming variations. Fig. 10 shows the core in place on the aspirator ready for testing when the cock at the top is

Fig. 7.—Ramming the Sand in Tube.

opened and the water in the cylindrical container escapes and sucks air through the core. The time taken for the water to fall from the extreme top of the aspirator to a fixed mark on the glass outlet tube is an index of the permeability.*

* For further description see Smalley's Paper, *loc. cit.*

Dry Sand and Loam Testing.

To obtain the strength of dry sand and loam two tests are made. A tensile test is rammed up in a British Standard cement mould, and a transverse test made on a bar of sand 6 in. long by

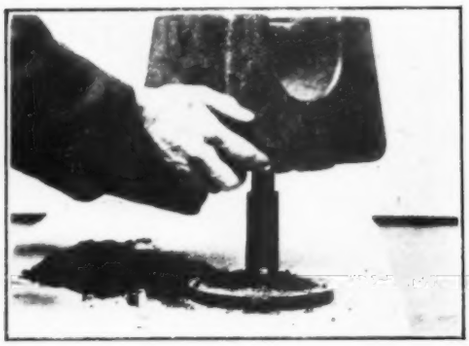

Fig. 8.—Applying Standard Pressure.

1 in. by 1 in. This latter test piece being made in the skeleton core box as used for the green dropping-test. These are now dried for about 4 hours at 450 deg. Fah. in an electric oven. Fig. 11 shows the oven with sample test-pieces in

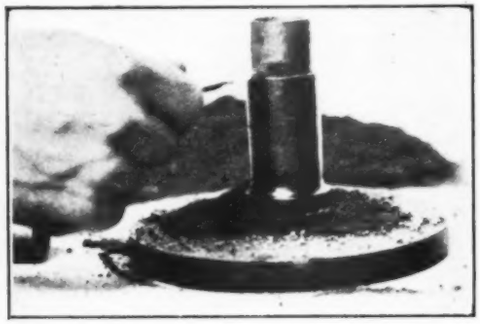

Fig. 9.—Gauging the Volume to be Used.

the front. After drying and cooling to room temperature these test pieces are broken as shown in Figs. 12 and 13. The tensile bar is placed in steel grips, and a bucket suspended, to which weights are added. In this case the bucket was omitted and a different kind of load applied which indicates the excellent strength shown

Fig. 10.—Test Core in Place in the Aspirator.

by some moulding compositions. The test piece in question was made from sea sand plus 2½ per cent. of linseed oil, and was 1 in. square at the breaking face. Fig. 13 shows a transverse test piece under load. In this case the test piece is supported from 4-in. centres, and the load applied centrally, through a ¼ in. diameter bar. The breaking load in either case is obtained in ozs. per sq. inch.

The permeability test for dry-sand work is rammed up in a split core box to give a 3 in. long by 1 in. dia. column of sand This is dried exactly the same as the previous test pieces, and when cold is mounted in a glass funnel with wax. Fig. 14 shows the core box and mounted test piece under test in the aspirator, and Fig. 15

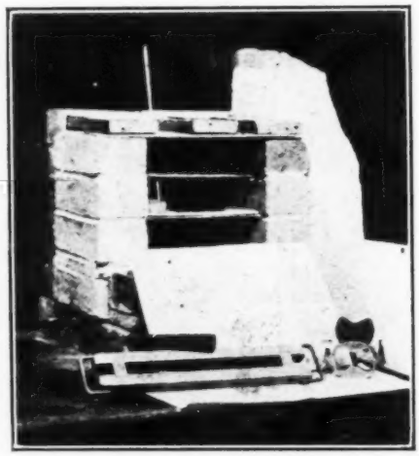

Fig. 11 shows the Oven, with Sample Test Pieces at its Front.

gives a close-up view of the mounted test piece. The method of mounting is as follows:—When the test piece is cool ¼ in. of the length is cut away, and holding the test piece by the end it is immersed in paraffin wax. Two immersions are required. (It is important to have the wax at the correct temperature, for if the wax is too hot then the wax will penetrate the test piece. On the other hand, if the wax is too cold, air leakage will take place.) The dipped test-piece is now

Fig. 12.—Tensile Testing Apparatus. The Test Piece is an Oil-Sand Mixture, and is only 1-in. square at the Breaking Face.

placed in the funnel, and plasticine pressed into position at the base to prevent the wax leaking into the funnel stem. Molten wax is now poured into the funnel around the test piece. When firmly set at the top of the test piece is cut open as shown.

In conjunction with these tests, wherever possible, a further test is applied to give an index of the skin producing and refractory powers of the sands. In this case a mould was made in the foundry, as outlined in Fig. 16, when all the sands examined could be made up into 2 in. wide blocks to form the base. These blocks are made from individual virgin sands in the dried condition, each being rammed as hard as possible with the

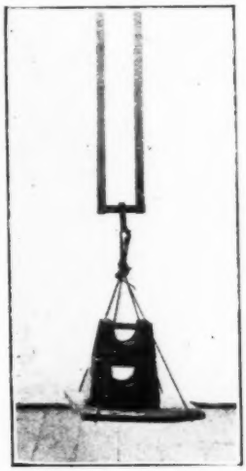

Fig. 13.—Tensile Machine Normally Loaded.

same moisture content. Two ladles of hot iron are now poured into the mould to produce a block 34 in. long by 5 in. wide by 2½ in. thick. When cold, if the block be extracted carefully,

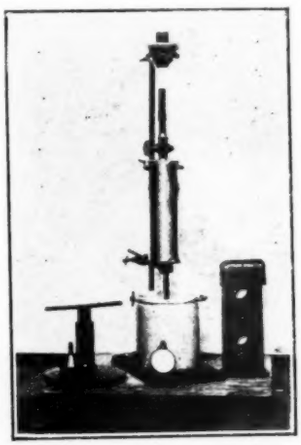

Fig. 14.—Permeability Testing Apparatus.

the refractoriness of the various sands can be gauged according to the amount of sand fritting which has taken place, and the skin-producing powers readily shown after sand blasting.

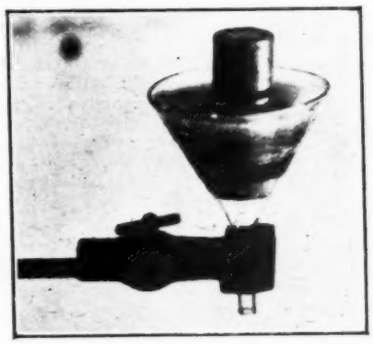

Fig. 15.—The Mounted Test Piece.

Some Common Scotch Moulding Sands.

The tests just described were applied to twenty-one different Scotch sands, five of them being

red sands, thirteen of the rotten-rock group, and three silica sands. Fig. 17 gives the results of Fletcher's subsidence test on these sands. The continuous lines on this graph are silica sands, the crossed lines red sands, and the dotted lines the rotten-rock class of naturally-bonded moulding

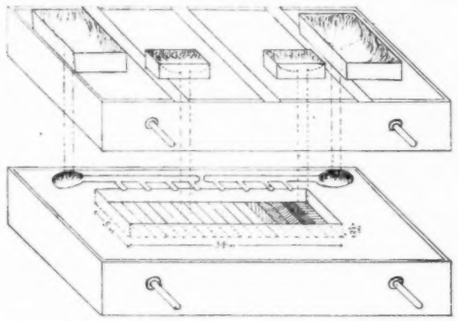

Fig. 16.—Refractoriness and Skin Producing Test Mould.

sands. It will be noticed that on the extreme left there is a straight line representing Irvine sea sand, whilst at the extreme right a curve representing common clay. The straight-line graph denotes a fairly uniform-graded sand, free from the clay and silt grades. This sand subsided in the test tube at an equal rate according to intervals of time. On the other hand, the graph representing clay subsided uniformly for a few seconds and then the subsidence became gradually slower and slower, shown by the bend in the graph This bend represents the point when the sand grains have subsided and the beginning of the clay subsidence.

As 3 ins. of dry sand was used in the test tube for all the sands, it is obvious that those sands, having their graph extremities on the 3 in. line, contain a relatively small proportion of clay and silt grades. All others contain different clay contents according to the amount of final subsidence between 1 to 3 in. For practical purposes it can be said that all sands having a straight line graph with an extremity on the 3 in. line contain no clay. Irvine sea sand and Kilwinning silica sand belong to this class. Furthermore, the lower the incline of the graph then the finer the texture of the sand. In this respect it should be noticed that Irvine sea sand is the coarsest sand examined, whilst Blairgowrie sand is the finest. Those sands having a bend in the graph near their extremity on the 3 in. line contain little or no clay, but perhaps a small amount of silt. Examples of these are typified by the sands shown between and including Caldwell silica sand and Wigtonshire red sand. Other sands between Loudoun rock (not milled) and clay contain a varying percentage of clay, the greater as they approach this latter sand. An exception to this, however, is shown by Blairgowrie sand, which contains surprisingly little clay, as is shown by its straight line curve, and its position is due to its extremely fine texture and the short period of the test. From this graph the relative texture and clay content can be seen at a glance, and it is of surprising value in distinguishing between different grades of similar coloured sands, as the complete test takes only about 5 minutes. It is to be preferred over the sieve test as regards time and simplicity, and also in regard to the ease in comparison of the various sands.

Table III shows the results obtained on the sieve test, and the strengths and permeability of the sands when used for green and dry sand work. These figures have been rechecked, and each is the average of two test-pieces. From this table it is possible to foresee the value of each sand for the various branches of moulding, and the suitability of sands for casting different alloys. It is also invaluable for making up new sand mixtures, as it is possible to obtain a far better idea of the physical properties of the mixture when the properties of the sand added to that mixture are known. It is interesting to note that the sieve tests on the red sands and silica sands check with Fletcher's subsidence test as an indication of sand texture, but the other sands containing clay are inclined to vary. This is no doubt due to the clay coating on the sand grains not being removed, as described earlier.

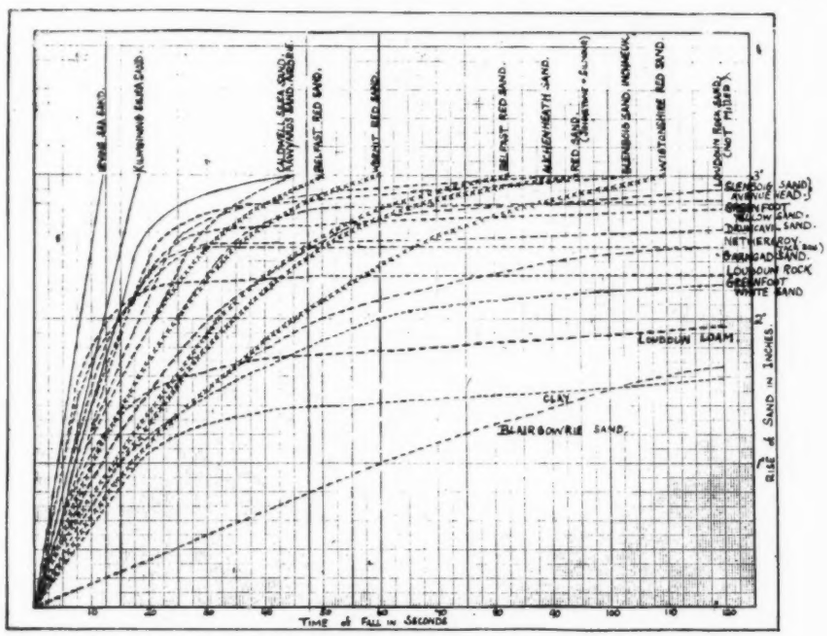

Fig. 17.—Subsidence Test Results on Scottish Moulding Sands.

It is interesting to note that most sands have less strength in the green condition when the moisture content exceeds 7 per cent., and higher permeability for the same degree of mould ramming. The water content of sand used for green sand moulding is of vital importance, and should be about 7 per cent. If this is exceeded trouble is bound to arise, as a study of the results in this table will show. All sands, however, will vary considerably in this respect, as some sands can take more water than others yet give the same results. As an example, take Belfast sand, No. 3 in the table, which is considerably used in this district for brass moulding. At 7 per cent. moisture tested in the green condition a green dropping test of 2.1 in. is obtained, with a permeability of 104 seconds. At 10 per cent. moisture the green dropping test remains the same, but the permeability is increased to 117 seconds. *In this sand excess water makes very little difference.* On the other hand, looking at Carlisle sand, which is also a good brass-moulding sand the green dropping test at 7 per cent. moisture is 3.4 in. with a permeability of 208 secs., and at 10 per cent. moisture the green dropping test 2.4 in., with a permeability of 381 secs. *In this case the extra 3 per cent. of moisture has resulted in a 30 per cent. reduction in strength and an 86 per cent. increase in permeability.* Exceptions to this rule are seen in Nethercroy sand, Loudoun loam and clay. In Nethercroy a better sand is obtained at 10 per cent. moisture for green sand work than at 7 per cent. The other two cases mentioned require the extra water to wet the large amount of clay present.

For dry sand work it is preferable to have 10 per cent. of moisture in the sand used, as the extra moisture *increases* the strength of the sand after drying. It is also interesting to note that the transverse strength can vary from 5 ozs. per sq. inch up to 189 ozs. per sq. inch, whilst the permeability ranges from 53 secs. up to 1,142 secs., with the same amount of ramming and moisture. Surely this is an excellent reason to learn more about the sands used? In selecting the most suitable sand for dry sand moulding it is a very good rule to choose a sand which will give high strength and low permeability together. For green sand work a sand should be selected which will give over 2½ in. green dropping test and have a permeability under 60 secs. at 7 per cent. moisture. Obtaining exact practical limits for a mixture specification has, so far, not been obtained for green sand work, but with the foundry sand testing apparatus this can be obtained.

Suitable sands for aluminium and brass moulding are typified by the finer red sands such as Belfast and Carlisle. For cast iron, with the exception of Blairgowrie sand, all the sands can be put to useful purpose, whilst those of value for steel work consist of Auchenheath, Inchneuk, Ranyards, Avenuehead, Greenfoot white, Caldwell and Kilwinning silica sands.

Fig. 18 shows the difference in refractoriness and skin production between red sand of the

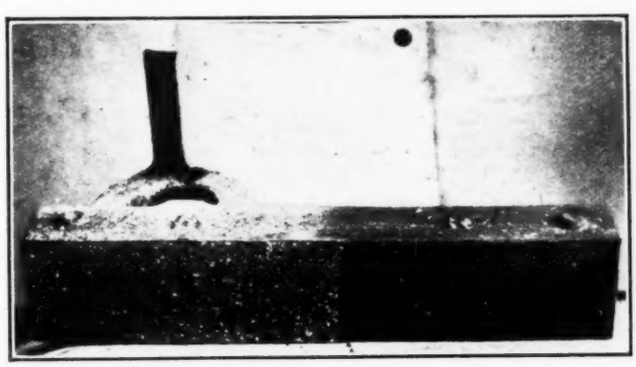

Fig. 18 shows Difference in Refractoriness and Skin Production Between Two Typical Sands.

Table III.—*Scottish Moulding Sands.*

Name of sand.	Sieve Test. Mechanical grading on dry sample (per cent.)								Rational analysis.		Tested Green. At 7 per cent. moisture.		Tested Green. At 10 per cent. moisture.		Dried at 450 degs. F. At 7 per cent. moisture.			Dried at 450 degs. F. At 10 per cent. moisture.		
	Passes 20	Passes 30	Passes 40	Passes 60	Passe 80	Passes 90	Passes 100	Passes 120	Per cent. Clay.	Per cent. Sand.	Dropping test.	Perm. in secs.	Dropping test.	Perm. in secs.	Tensile ozs. per sq. in.	Trans. ozs. per sq. in.	Perm. in secs.	Tensile ozs. per sq. in.	Trans ozs. per sq. in.	Perm. in secs.
Red Sands.											Ins.		Ins.							
1. Belfast. G. Walker, Sons & Co.	99.55	99.35	99.01	95.93	84.48	78.73	76.05	52.26	1.6	98.4	2.1	102	—	—	227	30	124	—	—	—
2. Wormit	99.66	99.65	99.51	98.64	89.59	83.77	79.09	58.85	1.8	98.2	2.1	107	2.08	147	153	32	161	274	45	186
3. Belfast	99.39	99.30	99.09	98.18	90.75	86.28	82.57	64.01	5.0	95.0	2.1	104	2.1	117	120	20	113	224	50	136
4. Carlisle Johnstone & Gilmour ..	99.77	99.14	98.24	96.55	93.36	90.00	87.17	67.52	14.2	85.8	3.4	208	2.4	381	206	50	227	396	66	414
5. Wigtonshire. G. Walker, Sons & Co.	100.00	100.00	99.90	99.60	99.20	97.68	96.26	87.17	1.6	98.4	2.06	120	—	—	31	13½	148	—	—	—
Rotten Rocks.																				
6. Ranyards sand.—Airdrie	97.65	96.24	94.35	87.78	74.50	56.13	53.23	38.14	5.9	94.1	1.9	63	1.9	90	42	9	83	69	17	94
7. Auchenheath sand ..	98.06	97.40	96.47	90.80	52.05	37.51	31.47	16.09	14.3	85.7	1.8	46	1.77	63	45	12	62	74	19	91
8. Glenboig sand. Inchneuk	95.64	92.49	86.60	70.95	28.27	21.35	18.05	9.30	32.5	67.5	1.8	48	1.8	62	308	54	52½	420	112	220
9. Glenboig sand. Avenuehead	96.18	94.86	92.46	82.22	32.90	23.05	18.42	9.39	33.3	66.7	3.1	64	—	—	248	43	74	—	—	—
10. Greenfoot yellow ..	98.77	95.79	87.00	56.19	16.57	12.33	9.93	5.21	27.7	72.3	2.3	46	1.9	48	92½	19	47	298	89	53
11. Drumcavil sand	97.51	94.20	90.85	82.85	30.19	20.62	15.10	7.45	44.7	55.3										
	97.3	93.5	89.95	83.1	34.5	23.4	19.15	10.1	31.6	68.4	3.2	65	2.8	102	412	55	70	730	141	90
12. Nethercroy sand ..	93.94	75.85	53.39	26.20	10.64	9.36	6.88	5.03	47.3	52.7	2.7	53	2.8	44	409	125	59	673	142	53
13. Garngad sand	95.99	94.27	91.40	86.19	65.80	53.60	35.54	27.63	37.5	62.5	2.7	130	2.3	303	195	47	149	245	77	316
14. Loudoun Rock	90.71	89.55	88.39	80.82	63.11	52.84	46.68	35.66	27.3	72.7										
	92.72	80.86	70.17	51.24	30.55	26.75	24.08	17.27	34.3	65.7	3.4	64	2.35	140	272½	49	186	478	121½	1,142
15. Greenfoot white.. ..	92.58	82.65	68.05	43.54	20.61	18.26	14.07	10.34	43.2	56.8	3.26	54½	2.8	81	236	54	53	787	189	304
16. Loudoun Loam	96.64	87.59	76.84	57.90	37.53	34.16	31.28	25.99	42.6	57.4	2.0	110	4.0	197	65	6½	81	692½	168	327
17. Blairgowrie sand ..	100.00	100.00	100.00	100.00	99.94	99.89	99.87	99.70	4.1	95.9	3.0	321	2.96	416	28½	5	471	27	5	545
18. Clay	86.21	79.15	69.89	62.09	49.06	46.78	42.47	37.93	63.5	36.5	This was tested at 14 per cent. moisture, as below material was too dry to work.									
											8.8	571	—	—	2,857	992	Impermeable on Apparatus.			
Silica Sands.																				
19. Irvine Sea sand ..	96.59	94.01	90.97	77.85	26.89	14.42	9.85	1.72	Nil	100.00	1.2	44	—	—	—	—	—	—	—	—
20. Kilwinning sand ..	98.52	97.32	94.44	73.96	23.69	15.07	13.00	5.91	1.3	98.7	1.2	44	—	—	—	—	—	—	—	—
21. Caldwell coarse sand ..	82.04	61.30	46.35	27.83	13.03	10.70	9.65	6.39	1.6	98.4	1.0	37	(Furnace sand)							

Bunter class and rock sand of the rotten-rock group. The red sand gives a finer skin and fettling easier when tested for grey iron castings. Fig. 19 illustrates the results obtained on all the Scottish sands tested for similar properties. In this test the sand of outstanding merit as regards refractoriness and skin production was Blairgowrie sand. The other sands are shown arranged in their order, those bracketed together having equal merit.

Fig. 20 gives some idea of the excellent refractoriness and skin-producing power of Blairgowrie sand. This is a close-up view of the block, illustrated in Fig. 19, immediately after lifting from the mould. No fettling has been done, and a perfect skin has been produced without any facing or admixture to the sand whatsoever. On one side of the skin produced by Blairgowrie sand there is the blown surface produced by the clay, and on the other the fritted and adhering burnt sand from Loudoun loam. It would seem that this property of Blairgowrie sand is due to its high mica-schist content. Unfortunately for the foundryman, this sand has rather a high-permeability and a very weak bond in the dried condition which mitigates against its successful use for general grey iron castings. If the physical properties of the sand had been normal it would be entirely practical to obtain a perfect skin on iron castings up to 2½ in. thick without using plumbago or blacking. However, the knowledge of the skin-producing properties of various sands is worth knowing, and it has been found possible to improve the appearance of castings by the results so far obtained.

(To be continued.)

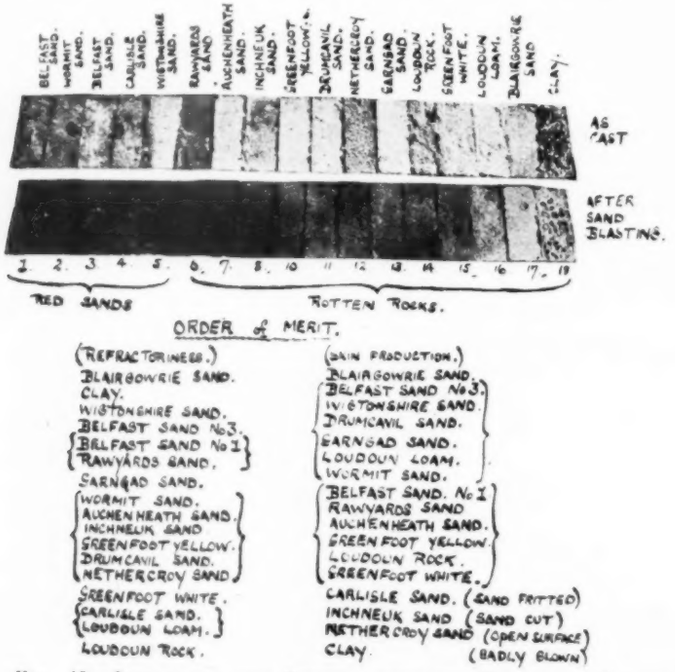

Fig. 19.—Illustrates the Results from the Testing of Various Scottish Sands.

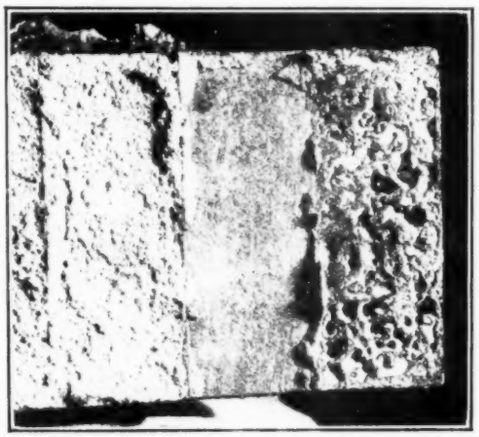

Fig. 20.—Shows the Results Obtained from Blairgowrie Sands.

The Leeds Forge Company, Limited, of Leeds, have received an order from the South African Railway Administration for 100 dropsided steel bogie wagons, each of 80,000 lbs. capacity.

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Trade Talk.

Vickers-Armstrongs, Limited, have secured an order from the Bombay Port Trust for a ship-shape caisson for the communication passage between Princes and Victoria Docks, Bombay.

A fire occurred at the works of C. Whitehouse & Sons, edge-tool manufacturers, Bridgtown, in Cannock, on Thursday, March 29, but was subdued before any serious damage was done.

Goldschmidt, Hayes & Smith, Limited, Mount Street, New Basford, Nottingham, have been appointed sole agents for Great Britain by the Renory Rope & Twine Works, Limited, Belgium, makers of steel and hemp ropes, etc.

The imports of foreign iron ore at the Prince of Wales' dock at Workington for the quarter ending March 31 have amounted to 37,000 tons, compared with 19,400 tons for the last three months of 1927. The ore imports for March amounted to 7,800 tons, against 4,150 tons for February.

A further meeting of the Enamelled Hollow-ware Committee, which is considering the question of a duty on imported enamelled hollow-ware, will be held at 10.30 a.m. on Friday, April 13, in room 74, first floor, at the Board of Trade, Great George Street, Westminster, S.W.1.

The joint secretaries of the Scottish Manufactured Iron Trade Conciliation and Arbitration Board have been informed by the accountant that the average net selling price of Scottish manufactured iron for January and February is £10 13s. 3.825d. This means that there will be no change in the wages of the workmen.

The Hunslet Engine Company, Limited, have just received an order from the London Midland and Scottish Railway Company for a further batch of twenty-five new locomotives, similar to those previously built. This is the fourth order received by the company from the L.M. and S. Railway, and will complete a total of 90 locomotives.

Robert Middleton & Company, Sheepscar Foundry, Leeds, are retiring from business, and have disposed of the goodwill, drawings and patterns to Rose, Downs & Thompson, Limited, of Hull. The experience of Rose, Downs & Thompson as hydraulic and general engineers covers an unbroken period of 150 years, and their works, machine shops and foundry are amongst the most up-to-date and best equipped in the North of England.

According to the annual report of the Manchester Steam Users' Association, the total number of examinations made of boilers during 1927 was 26,768. Of these, 11,421 were those known as "Internal," "Flue," and "Entire," the number of such examinations being practically equal to the number of boilers under the Association's enrolment. The committee are again in a position to state that no preventable explosion has occurred of any boiler which has carried its guarantee and certificate of safety.

Mr. H. P. Macmillan has accepted a joint invitation from the Shipbuilding Employers' Federation and the shipyard trade unions to act as the independent chairman of the National General Conference under the conciliation machinery agreements concluded between the employers and the trade unions in the shipbuilding industry last year. The whole of the shipyard unions are parties to these agreements except the Boilermakers' Society, with whom the employers are still in touch regarding the adoption of a similar provision.

Mr. W. Farmer, secretary of the Royal Metal Trades' Pension and Benevolent Society, 195, Upper Thames Street, E.C.4, announces that the second annual golf competition for the president's silver challenge cup will be held on Wednesday, May 16, at Sundridge Park Golf Club, Bromley, Kent. All subscribers and donors of the Society are eligible to compete, and those desirous of entering are requested to send their names to the secretary not later than Friday, May 11. When entering their names competitors should send their entrance fee of 10s. each, which includes green fee, stating at the same time the name of their golf club and lowest club handicap (maximum 18).

The Power-Gas Corporation, Limited, Stockton-on-Tees, have recently secured an order from Synthetic Ammonia & Nitrates, Limited, Billingham, for the fourth extension to the water-gas and producer-gas plant which they originally installed for the company. The present order includes nine mechanical water-gas generators with waste heat boiler equipment, auxiliaries and automatic control, also four mechanical producer-gas generators with auxiliary equipment, together with building for housing the plant and overhead fuel bunker. The installation, with this extension completed, will comprise twenty-one water-gas generators and eight producer-gas generators, together capable of a total gas output of 4½ million cubic feet per hour.

The wages regulated by the sliding scale under the Midland Iron and Steel Wages Board will remain unaltered from Monday, April 9, to Saturday, June 2.

The Staveley Coal and Iron Company, Limited, near Chesterfield (Foundry Sales Department), announce that amongst other orders for cast-iron pipes recently received are the following:—Mr. I. Rees (Maesteg), contractor to Mid-Glamorgan Water Board, 1,000 tons 14 in. dia.; Wm. Wilson & Company (Newcastle), Limited, contractors to Welwyn Garden City authorities, 450 tons 3 in. to 6 in. dia.; Durban Corporation, 220 tons 4 in. to 30 in. dia.; Southport Birkdale and West Lancashire Water Board, 365 tons 15 in. dia.; County Kerry Board of Health, 325 tons 4 in. and 6 in. dia.; Stockport Corporation Water Department, 180 tons 6 in. and 7 in. dia.; Warrington Corporation Water Department, 150 tons 3 in. to 6 in. dia.; Oxford Corporation Gas Department, 120 tons 18 in. and 24 in. dia.; Ipswich Corporation Gas Department, 160 tons 3 in. to 6 in. dia.; Burnley Corporation Water Department, 220 tons 12 in. dia.; L. M. and S. Railway Company, 220 tons 6 in. and 10 in. dia.; Mexborough Council Water Department, 250 tons 8 in. dia.; Monte Video W. W. Company, Limited, 450 tons 5 in. and 7 in.

Col. Trinham, presiding at the annual meeting of the Midland Iron and Steel Wages Board, held in Birmingham on Wednesday, March 28, said prices throughout the year had continued to droop, and the quantities of material manufactured had fallen. The return on capital invested in the iron and steel industry in the United Kingdom was poor, in Germany fair, in the United States and France considerable, and in Belgium very high. Why should Belgium, whose prices were the lowest, have a very high return on capital? He had seen up-to-date ironworks in Belgium and France built on the site of old works destroyed by the Germans. The rebuilding costs had been largely, if not entirely, borne by the Government. It was not necessary to emphasise the influence which the importance of foreign material had upon the basic industries of this country, and particularly in the wrought iron trade. Those associated with the basic industries must judge the effect of that by reason of the lower taxation and the much smaller extent of social service and the lower wages and longer hours which obtained on the Continent. He said without hesitation that the ability and enterprise of the employers generally and the character and ability of the British worker, other things being equal, would put them in an absolutely unassailable position.

Another new factory is being added to the Wolverhampton industrial sphere by Steelway, Limited, of Queen's Gate Works, Monmore Green, who have constructed a works for the production of pressed steel goods, principally patented steel flooring for power stations, factories, workshops and ships, on a site at Bilston Road. The new factory will eventually employ 200 to 300 workpeople, and will commence production soon after Easter. Its erection must be one of the speediest on record. Six weeks ago building commenced on the cleared site, and the premises are now all ready for the installation of the machinery. The works cover an area of one and a-half acres, and are constructed of steel, with brick-built offices. As far as Wolverhampton is concerned, this is an entirely new development, for amongst the many steel products of the firm will be the manufacture of stairways for ships. Owing to the patented design, the flooring used for the steps will be exceptionally light yet very strong and durable. Other products to be manufactured by the firm are fencing and gates, industrial trucks and trailers, fire escapes, fireproof doors, lathe parts, tanks and vats, safe linings and steel channels. The managing director is Mr. C. W. Goodyear, whose long experience with W. Goodyear & Sons, of Dudley, will be available for the new company. The other directors are Mr. F. H. Clark, of the Stourbridge Glazed Brick Company, and Mr. J. E. Bettles, who is the works manager.

Obituary.

The death occurred, on March 29, of Mr. Alfred Woodhead, general manager at Low Moor for Robert Heath & Low Moor, Limited. Mr. Woodhead entered the service of the old Low Moor Company as a boy in the office, and rose until he eventually succeeded his father as general manager. He retained this position up to the time of his death, though during the past year his health had been failing and he had largely been confined to bed. He suffered a serious blow recently by the death of the assistant manager, Mr. Walter Woodhead, his nephew, who had 55 years with the company.

Contracts Open.

Birkenhead, April 16.—Bolts, nuts, wood screws, cast-iron house service boxes, mains, boxes, etc., for the Corporation. Mr. F. E. Spencer, borough electrical engineer, Craven Street, Birkenhead.

Garriston, Leyburn, April 14.—Providing and laying 2,300 lineal yards of 3-in. steel pipes or alternatively cast-iron pipes, 500 lineal yards galvanised 1-in. diameter wrought-iron pipes, and 300 lineal yards galvanised ¾-in. diameter wrought-iron pipes, together with the construction of intake and storage tanks and appurtenant works, for the Garriston water supply. Mr. F. J. Rodwell, engineer, 37 and 38, Prudential Buildings, Park Row, Leeds. (Fee £1 1s., returnable.)

Glasgow, April 17.—Lighting materials, for the Corporation, viz.:—Brass mountings; electrical fittings and accessories; iron gas fittings; lamp pillars; tinplate, copper, etc. The Lighting Department, Trongate, Glasgow.

Hartley Wintney, April 18.—Construction of about 475 ft. of 2-in. cast-iron water main, together with fire hydrant and valve, for the Hartley Wintney Rural District Council. The Council Offices. (Fee £1 1s., returnable.)

Johannesburg, April 19.—Malleable iron or mild steel, for the Town Council of Johannesburg, viz., 600 malleable iron or mild steel Kimberley sockets, assorted: 3-in., 150; 4-in., 250; and 6-in., 200. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1. (Ref. A.X. 6082.)

Johannesburg, April 19.—Meter boxes, for the Council of Johannesburg, viz., 200 malleable cast-iron meter boxes. The Department of Overseas Trade, 35, Old Queen Street, London, S.W.1. (Ref. A.X. 6093.)

Leeds, April 16.—400 lineal yards of unclimbable iron fencing, for the Waterworks Committee. The Waterworks Department, 26, Great George Street, Leeds.

London, S.W., May 1.—175 tons of structural steelwork for pattern shop, for the Madras and Southern Mahratta Railway Company, Limited. (Fee £1 1s., non-returnable.) The offices, 25, Buckingham Palace Road, Westminster, S.W.1.

Manchester, April 12.—Construction and erection of wrought-iron entrance gates, for the Corporation. Mr. J. H. Sillitoe, secretary, Gas Department, Town Hall, Manchester.

Penpont, April 23.—Supplying and laying of 580 lineal yards of 2-in. diameter cast-iron pipes, etc. Mr. W. C. Easton, civil engineer, 183, West George Street, Glasgow. (Fee £1 1s., returnable.)

New Companies.

H. R. Burnham & Company, Limited.—Capital £12,000, to acquire mica, manganese, iron, copper, lead, or any other minerals, etc. Directors: H. R. Burnham (permanent director and chairman), and H. F. Bamber, Africa House, 44-46, Leadenhall Street, E.C.

W. & G. W. Garratt, Limited.—Capital £1,000 in £1 shares, to acquire business of ornamental ironworker and general smith carried on by W. Garratt at New Market Hotel Yard, Sheaf Street, Sheffield, Yorks., as W. & G. W. Garratt.

Lincoln Castings Company, Limited.—Capital £5,000 in £1 shares, to acquire business of ironfounders carried on by Sarah A. Horton, A. Ball and W. Clapham at Boultham, Lincoln, as Matthew Pearson.

Malleable Steel Foundry Company, Limited.—Capital £6,000, to acquire part of business of Malleable Steel Castings Company (1909), Limited. Directors: E. A. Walsh and W. R. Bardsley. Secretary: A. E. Draper, 1, Avon Road, Burnage Lane, Levenshulme, Manchester.

Monarch Metals, Limited.—Capital £1,000. Solicitors: Churchill, Clapham & Company, 1, Broad Street Place, E.C.2.

F. Parkin & Sons, Limited, Bonhay Foundry, Bonhay Road, Exeter.—Capital £20,000. Iron and brass founders. Directors: F., F. L., and F. J. Parkin.

Sheepbridge Stokes Engine Liners, Limited.—Capital £2,000. Directors: W. H. McConnell, F. W. Stokes and F. Skelton. Solicitor: Arthur M. Stokes, Linby, Notts.

Southampton Internal Combustion and General Engineering Company, Limited, Vespasian Road, Bitterne Manor, Southampton.—Capital £500. Directors: W. H. Truckle and V. R. King.

William Wilkinson & Sons (Penketh), Limited, Warrington Road, Penketh, Warrington.—Capital £1,500. Machine tool makers. Director: H. Houle.

The German Steel Trust and Krupps.—After negotiations extending over several months, Krupps have arranged a working agreement with the German Steel Trust (Vereinigte Stahlwerke A.-G.).

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Iron and Steel Markets.

Pig-Iron.

MIDDLESBROUGH.—In conformity with holiday traditions, the Cleveland iron market on Tuesday was closed this week, and business was consequently held over for a few days without much inconvenience either to buyers or sellers on this occasion. It is reported that the foundries, with few exceptions, are not very busy, and the holiday break will necessarily reduce consumption. The Tees-side ironmasters, however, are able to face the prospect with equanimity, since their stocks have been steadily declining for some time past and they have seldom had such small reserves of iron on hand. On the export side, the figures quoted hereafter show that there is some improvement, but it is very limited, and the position seems to be that, whilst foreign iron has been shut out of the home market, Cleveland iron can find few gaps in the European tariff walls. Cleveland prices are very firm, both to home and foreign consumers, on the following basis:—No. 1 Cleveland foundry iron, 68s. 6d.; No. 3 Cleveland G.M.B., 66s.; No. 4 foundry, 65s.; No. 4 forge, 64s. 6d.

During the month of March Tees shipments of pig-iron reached a total of 20,318 tons, which, though it represents an increase of only 1,907 tons on the February total, is the biggest export figure since the coal strike.

The slight improvement recently noted in the market for East Coast hematite has not been maintained for long, and at the moment business is again only possible on cut-throat competitive terms. Thus 70s. per ton is now generally quoted for mixed numbers and 70s. 6d. for No. 1 quality, and for some named brands slightly more has been paid. On the other hand, there are buyers who still claim to be able to do slightly better than 70s. per ton for mixed numbers. On the North-West Coast, in the meantime, prices are unchanged, with Bessemer mixed numbers 70s. per ton at furnaces.

LANCASHIRE.—For obvious reasons, business in the local markets for foundry pig has been practically idle this week, with prices unchanged from previous quotations, ruling about as follow:—For delivery in the Manchester area, Derbyshire brands are at from 72s. to 72s. 6d. per ton, Staffordshire at 71s. 6d., Cleveland at 79s. per ton, and Scottish at from 87s. 6d. to 90s. per ton.

THE MIDLANDS.—Pending the quarterly meeting next week, dealings in foundry pig are necessarily on a limited scale, and so far there have been few movements of importance as regards current prices, which may be quoted as follow:—Northamptonshire No. 3, 58s. 6d.; Derbyshire, 63s. 6d. to 64s. 6d.; North Staffordshire, 63s. 6d. to 64s. 6d. at furnaces; No. 3 Scotch iron, 90s. per ton. The furnaces are also quoting 72s. 6d. for Lincolnshire and 81s. 9d. per ton for Cleveland, delivered this area.

SCOTLAND.—As Eastertide is not recognised as a holiday period in this area, there has been no check in production, but the pig-iron market is quieter, due to the English works temporarily closing down. Notwithstanding the quieter demand, the pig-iron makers are firm on the basis of 70s. for No. 3 foundry at the furnaces. The Lincolnshire iron, which has been offering at about 2s. less than Middlesbrough as a substitute, is not suiting a number of the consumers, and they are only using it very sparingly. There is still no sign of Continental pig-iron being competitive with home irons, and purchases are being confined entirely to the latter.

Finished Iron.

Reports from the chief centres of this section of the industry record little improvement either in demand or in inquiries regarding fresh business, while export trade is also disappointing in results for the past month. In South Staffordshire the makers of marked bars remain fairly well situated for work, and the price of £12 10s. for marked bars is maintained. The price for crown iron continues to vary very considerably. Lancashire crown iron is being offered here at £9 to £9 5s., but most of the Black Country houses are asking in the neighbourhood of £10 for their crown bars. On the North-East Coast the manufactured iron and steel shipments amounted to 62,257 tons, of which 2,777 tons went coastwise. During the first quarter of the year the aggregate manufactured iron and steel shipments have reached only 186,488 tons, a monthly average of 62,163, compared with a monthly average of 71,547 tons during the whole of 1927. The decline seems to have been general, and is not counterbalanced by any material improvement in the home demand.

Steel.

Conditions generally in the British steel industry appear to have remained under a quiet phase, and there seems little anticipation of any considerable increase in demand after the Easter holidays. There is still keen competition for any orders that come into the market, as most of the home makers are not too well off for orders. In the Continental department manufacturers appear to be struggling to hold their prices, which, in spite of their efforts, have an easier tendency. At Sheffield a fair lot of acid billets are being disposed of, and soft qualities are the best feature of basic billets at the moment. The Association price of high-speed steel, 14 per cent. tungsten, has been dropped from 2s. 3d. to 2s. per lb. in order to give makers a better chance of meeting Continental competition. The 18 per cent. tungsten quality is unaltered at 2s. 9d. per lb. The production of special steels is expanding, and there are big orders for these on hand, but for ordinary steels only a moderate demand is reported. The tone of the tinplate market is quite firm, quotations ruling as follow:—Coke tins in approved specifications, 18s. to 18s. 3d. basis, with option of lights and crosses, and 3d. basis extra for squares and odd sizes, net cash, f.o.b. Wales.

Scrap.

As usually experienced at holiday times, business in the various markets for scrap metals has been virtually suspended, while prices, with few exceptions, are unchanged. At Middlesbrough cast-iron borings at 43s. are a quiet market, while ordinary heavy cast iron keeps steady and firm at 62s. per ton, but machinery quality is easy at 66s. In Scotland machinery cast-iron scrap is 70s. per ton, i.e., for pieces not exceeding 1 cwt.; for heavy cast-iron scrap to the same specification, 65s. per ton. Old cast-iron railway chairs are not too plentiful at 70s. per ton. Steelworks cast-iron scrap is 65s. per ton, and light cast-iron scrap is 60s. to 61s. 3d. per ton. The above prices are all per ton delivered f.o.t. consumers' works.

Metals.

Copper.—Allowing for holiday interruptions, the tone of the base metal markets has remained remarkably steady, warrant copper more especially retaining the firmer tendency reported previously. The outlook as regards consumption is considered satisfactory, although the takings on this side for electrical use are still relatively small. Sellers of warrant copper are distinctly more cautious, while the larger American producers are favourably situated, and the position on this side is well under the control of the Combine.

Official closing prices of standard copper have been as follows:—

Cash.—Thursday, £61 13s. 9d. to £61 15s.; Tuesday, £61 16s. 3d. to £61 17s. 6d.; Wednesday, £61 13s. 9d. to £61 15s.

Three Months.—Thursday, £61 15s. to £61 16s. 3d.; Tuesday, £61 17s. 6d. to £61 18s. 9d.; Wednesday, £61 13s. 9d. to £61 15s.

Tin.—The position in standard tin quotations continues steadier than for some time past, readily explained as the result of further important repurchases on the short side and the inevitably more stringent position of cash and near tin in consequence of the further considerable inroads on home stocks, which fell to 1,912 tons, against 2,376 tons previously. Compared with a few weeks ago, when stocks reached nearly 3,000 tons, there has therefore been a shrinkage of roughly 1,000 tons.

Official closing prices of standard tin have been as under:—

Cash.—Thursday, £237 5s. to £237 10s.; Tuesday, £235 7s. 6d. to £235 12s. 6d.; Wednesday, £230 12s. 6d. to £230 15s.

Three Months.—Thursday, £238 to £238 2s. 6d.; Tuesday, £235 15s. to £236; Wednesday, £231 10s. to £231 12s. 6d.

Spelter.—Discussing the conditions in ordinary spelter, H. Gardner & Company write that there are no signs of any revival of interest from consumers, and the galvanising trade is reported to be very quiet. Continental offering of spelter is still negligible, and, as consumption there is on the slow side, some accumulation of stocks is almost certainly taking place. The mid-monthly stocks in America increased by approximately 3,000 tons, but may be expected to show a deduction on this figure at the end of March.

The following are the week's prices:—

Ordinary.—Thursday, £25; Tuesday, £24 18s. 9d.; Wednesday, £24 15s.

Electro, 99.9 per cent.—Thursday, £29; Tuesday, £29; Wednesday, £29.

Lead.—The market for soft foreign pig continues restricted in the volume of business transacted, but the undertone is firm. Demand from consumers is rather idle, and, considering the ample supplies available the strength of the market is somewhat surprising. The Continent is idle, but, should demand spring up in that quarter, prices would probably advance further.

The week's prices are appended:—

Soft Foreign (prompt).—Thursday, £20 5s.; Tuesday, £20 2s. 6d.; Wednesday, £20.

English.—Thursday, £21 10s.; Tuesday, £21 10s.; Wednesday, £21 10s.

Continental Steel Trust.

As reported recently, the Skodawerke of Pilsen and the Poldihütte have withdrawn from the Central European group of the Continental Steel Trust, but no special importance is attached to this, as it cannot exercise any influence on the composition of the Trust, as neither of these Czech works were actually members of the Trust. Their output was only taken into account in order to fix the total quota for Czecho-Slovakia, as was done in the case of other groups without all the firms being represented in the Trust. The Skoda and Poldi works had hitherto reported their production tonnage, which they considered to be an undesirable control; their output figures will now be excluded from the Czech quota in the Central European group.

The main objection of the Central European group to the regulations of the Trust was in respect of the penalties for excess output. In order to settle this point a Committee was appointed at the last meeting of the Trust in Paris and proposals in this matter are shortly expected to be made. In principle the Central European group agreed to this method of arranging the matter, so that the unexpected withdrawal of the two works in question did not influence the attitude of the Czech works in Paris.

The next meeting of the Trust is to take place in the first half of June.

Reports and Dividends.

Harland & Wolff, Limited.—Net profit, £287,202; dividend, 6 per cent. on first preference; credit balance, £95,202, carried forward.

Alley & MacLellan, Limited.—Net profits for 1927, £17,230; brought forward, £14,811; dividend, 5½ per cent. on the preference shares; written off plant, £9,145; carried forward, £19,236.

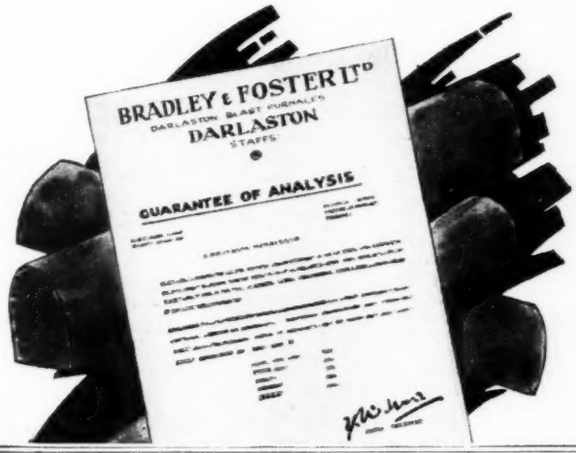
Coltness Iron Company, Limited.—Profit, £202,282; income-tax, £37,000; redemption and depreciation, £46,000; net profit, £119,282; ordinary dividend, 10 per cent.; brought in, £98,593; carry forward, £113,375.

Birmingham Small Arms Company, Limited.—Net profit, £202,063; brought forward, £289,713; dividends on 5 per cent. "A" and 6 per cent. "B" preference shares; carry forward, £336,822; no dividend on ordinary shares.

Budapest International Fair.—The Budapest International Fair will be held from April 28 to May 7 next, when more than one hundred branches of industry will be represented. Hungarian products will, of course, predominate, but there will also be a fine exhibition of manufactured goods from fourteen foreign countries. Particulars of the Fair can be obtained from the Royal Hungarian Legation, 53, Chester Square, London, S.W.1.

The Demag Revolving Electric Furnace.—We regret to state that an error occurred in the article on the Demag revolving electric furnace, which appeared on page 239 of the Foundry Trade Journal of April 5. Under the subsidiary heading of *Quantity Melted* (*b*) brass (60 Cu : 40 Zn) the casting temperature should read 1,050 to 1,100 deg. C., not 1,050 to 2,200 deg. C. The electrode consumption for smelting gunmetal and bronze should, of course, be per ton of metal melted in each instance.

WHAT THE BRADLEY SERVICE MEANS TO THE FOUNDRYMAN. No. 1.



THE SMALLEST CONSIGNMENT ANALYSED AND GUARANTEED

Foundrymen in the Midlands will be interested to know that in addition to Refined Pig Iron, Bradleys are able to supply from stock, various brands of Hematites, Scotch, Derbyshire, and Northampton Foundry Pig Iron, for mixing purposes.

The smallest consignment is carefully analysed and recorded and the exact quality can be guaranteed. This is just an instance of the Bradley Service, giving full assurance to the small founder who wants, say a soft iron for his mixture. With the Bradley Service he gets what he wants and knows exactly what he has got, at very little more than he would pay for an ordinary quality sold without any guarantee. It pays to use the Bradley Service whether your requirements are big or small.

Make full use of The Bradley Service

Bradley's

PIG IRON

"A QUALITY FOR EVERY REQUIREMENT"

Write or 'phone for particulars of the Bradley range of Refined Pig Irons. Immediate attention is given to all enquiries and the knowledge and long experience of Bradley's is at the disposal of all foundrymen.

BRADLEY & FOSTER LTD BF DARLASTON, STAFFS.

WEEKLY PRICE CURRENT.

COPPER

	£ s. d.
Standard cash	61 13 9
Three months	61 13 9
Electrolytic	66 10 0
Tough	64 5 0
Best selected	64 10 0
Sheets	92 0 0
India	76 0 0
Wire bars	66 12 6
Do. April	66 12 6
Do. May	66 12 6
Ingot bars	66 12 6
H.C. Wire rods	71 10 0
Off. av. cash, March	61 3 6 5/32
Do. 3 mths., March	61 3 0 7/11
Do., Sttlmnt., March	61 3 6 7/11
Do., Electro, March	66 12 2 25/32
Do., B.S., March	65 1 11 1/2
Aver. spot price, copper, Mar.	61 3 7
Do., Wire bars, March	66 15 6 3/4
Solid drawn tubes	13d.
Brazed tubes	13d.
Wire	9 5/8d.

BRASS.

Solid drawn tubes	11 1/2d.
Brazed tubes	13 1/2d.
Rods, drawn	10 1/2d.
Rods, extd. or rlld.	7 1/2d.
Sheets to 10 w.g.	10 1/2d.
Wire	9 1/2d.
Rolled metal	9 1/2d.
Yellow metal rods	7 1/2d.
Do. 4 × 4 Squares	8d.
Do. 4 × 3 Sheets	8 1/2d.

TIN.

	£ s. d.
Standard cash	230 12 6
Three months	231 10 0
English	235 10 0
Bars	237 10 0
Straits	234 10 0
Australian	232 0 0
Eastern	240 5 0
Banca	237 0 0
Off. av. cash, March	232 16 5 5/32
Do., 3 mths., March	234 0 1 1/32
Do., Sttlmt., March	232 15 2 31/32
Aver. spot, March	232 16 5

SPELTER.

Ordinary	24 15 0
Remelted	25 0 0
Hard	20 0 0
Electro 99.9	29 0 0
English	25 5 0
India	21 10 0
Zinc dust	33 0 0
Zinc ashes	8 0 0
Off. aver., March	25 0 5 1/16
Aver., spot, March	25 1 7 1/2

LEAD.

Soft foreign ppt.	20 0 0
English	21 10 0
Off. average, March	20 2 10 1/32
Average spot, March	19 18 9

ZINC SHEETS, &c.

Zinc sheets, English	33 10 0
Do. V.M. ex whf.	32 0 0
Rods	39 0 0
Boiler plates	29 10 0
Battery plates	31 5 0

ANTIMONY.

Special brands, Eng.	58 0 0
Chinese	41 10 0
Crude	34 0 0

QUICKSILVER.

Quicksilver	22 7 6

FERRO-ALLOYS AND STEEL-MAKING METALS.

Ferro-silicon—	
25%	8 2 6
45/50%	12 17 6
75%	20 10 0
Ferro-vanadium—	
35/40%	14/3 lb. va.
Ferro-molybdenum—	
70/75% c. free	4/6 lb.
Ferro-titanium—	
23/25% carbonless	11d.
Ferro-phosphorus, 20/25%	£17 15 0
Ferro-tungsten—	
80/85%, c. fr.	1/3 lb.
Tungsten metal powder—	
98/99%	1/7½ lb.
Ferro-chrome—	
2/4% car.	£32 15 0
4/6% car.	£22 8 0
6/8% car.	£22 5 0
8/10% car.	£22 5 0
Ferro-chrome—	
Max. 2% car.	£35 0 0
Max. 1% car	£40 0 0
Max. 0.70% car	£47 0 0
70%, carbonless	1/2 lb
Nickel—99%, cubes or pellets	£175 0 0
Ferro-cobalt	9/6 lb.
Aluminium 98/99%	£105 0 0
Metallic chromium—	
96/98%	2/10 lb.
Ferro-manganese (net)—	
76/80%, loose	£13 10 0
76/80%, packed	£14 10 0
76/80%, export	£13 5 0
Metallic manganese—	
94/96%, carbonless	1/10 lb.

Per ton unless otherwise stated.

HIGH-SPEED TOOL STEEL.

Finished bars, 14% tungsten	£0 2 3
Finished bars, 18% tungsten	£0 2 9

Per lb. net, d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under ½ in. to ¼ in.	3d. lb.
Do., under ¼ in. to 7/32 in.	1/- lb.
Flats, ½ in. × ¼ in. to under 1 in. × ⅛ in.	3d. lb.
Do., under ½ in. × ¼ in.	1/-lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

Scrap from high-speed tool steel—	
Scrap pieces	3d.
Turnings and swarf	1d.

Per lb. net, d/d steel makers' works.

SCRAP.

	£ s. d.
South Wales—	
Hvy. steel	3 5 0
Bundled steel and shrngs.	2 16 6 to 3 2 6
Mixed iron and steel	2 17 6 to 2 18 6
Heavy cast iron	3 0 0
Good machinery for foundries	3 2 6 to 3 5 0
Cleveland—	
Heavy steel	2 17 6
Steel turnings	2 9 6
Cast iron borings	2 3 0
Heavy forge	3 10 0
Bushelled scrap	3 2 6
Cast-iron scrap	3 2 0 to 3 6 0
Lancashire—	
Cast-iron scrap	3 5 0
Hvy. wrought	3 2 6
Steel turnings	2 2 6
London—Merchants' buying prices delivered yard.	
Copper (clean)	52 0 0
Brass (clean)	38 0 0
Lead (less usual draft)	17 10 0
Tea lead	15 10 0
Zinc	16 0 0
New aluminium cuttings	75 0 0
Braziery copper	47 0 0
Gunmetal	48 0 0
Hollow pewter	165 0 0
Shaped black pewter	125 0 0

PIG-IRON.

(f.o.t. unless otherwise stated.)

N.E. Coast—	
Foundry No. 1	68/6
Foundry No. 3	66/-
Foundry No. 4	65/-
Forge No. 4	64/6
Hematite No. 1	70/6
Hematite M/Nos.	70/-
N.W. Coast—	
Hem. M/Nos. d/d Glas.	82/6
,, d/d Birm.	86/6
Midlands—	
Staffs. common*	—
,, No. 4 forge	62/6
,, No. 3 fdry.	64/6
Shrops. basic	—
,, Cold blast, ord.*	—
,, ,, roll iron*	—
Northants forge	—
,, fdry. No. 3	58/6 to 59/-
Derbyshire forge	60/-
,, fdry. No. 3	64/-
,, basic	—
Scotland—	
Foundry No. 1	—
,, No. 3	70/-
Hem. M/Nos.	75/-
Sheffield (d/d district)—	
Derby forge	64/6
,, fdry. No. 3	67/6
Lincs. forge	63/6
,, fdry. No. 3	67/-
E.C. hematite	82/6
W.C. hematite	85/-
Lincs. (at furnaces)—	
Forge No. 4	63/6
Foundry No. 3	67/-
Basic	66/-
Lancashire (d/d eq. Man.)—	
Derby forge	—
,, fdry. No. 3	72/3
Northants foundry No. 3	58/6
Dalzell, No. 3	100/- to 102/6
Summerlee, No. 3	86/6 to 94/-
Glengarnock, No. 3	86/6 to 94/-
Gartsherrie, No. 3	86/6 to 94/-
Monkland, No. 3	86/6 to 94/-
Coltness, No. 3	86/6 to 94/-
Shotts, No. 3	86/6 to 94/-

* d/d Birmingham.

FINISHED IRON AND STEEL.

Usual District deliveries for iron ; delivered consumers' station for steel.

Iron—	£ s. d.	£ s. d.
Bars (cr.) nom.	9 0 0 to 10 10 0	
Angles	—	
Tees to 3 united ins.	—	
Nut and bolt iron	8 17 6	
Hoops	12 0 0	
Marked bars (Staffs.) f.o.t.	12 10 0	
Gas strip	12 0 0	
Bolts and nuts, ¾ in. × 4 in.	15 5 0	
Steel—		
Ship plates	8 7 6 to 8 12 6	
Boiler plts.	10 10 0	
Chequer plts.	10 5 0	
Angles	7 17 6	
Tees	8 17 6	
Joists	7 17 6	
Rounds and squares, 3 in. to 5½ in.	7 10 0	
Rounds under 3 in. to ⅜ in. (Untested)	7 15 0 and upwards	
Flats, over 5 in. wide and up	8 17 6	
Flats, 5 in. to 1½ in.	7 17 6	
Rails, heavy	8 2 6 to 8 7 6	
Fishplates	12 10 0	
Hoops (Staffs.)	10 10 0	
Black sheets, 24g.	10 0 0	
Galv. cor. shts., 24g.	13 2 6	
Galv. fencing wire 8g. plain	12 10 0	
Billets, soft	£6 0 0 to 6 10 0	
Billets, hard	£7 2 6 to 7 12 6	
Sheet bars	£5 12 6 to 5 15 0	
Tin bars	£5 12 6 to 5 15 0	

PHOSPHOR BRONZE.

	Per lb. basis.
Strip	1 2½
Sheet to 10 w.g.	1 3
Wire	1 3½
Rods	1 3
Tubes	1 8½
Castings	1 2

Delivery 3 cwt. free.
10% phos. cop. £40 above B.S.
15% phos. cop. £50 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. Clifford & Son, Limited.

NICKEL SILVER, &c.

	per lb.
Ingots for raising	9d. to 1/3
Rolled—	
To 9 in. wide	1/3 to 1/9
To 12 in. wide	1/3½ to 1/9½
To 15 in. wide	1/3½ to 1/9½
To 18 in. wide	1/4 to 1/10
To 21 in. wide	1/4½ to 1/10½
To 25 in. wide	1/5 to 1/11
Ingots for spoons and forks	9d. to 1/5½
Ingots rolled to spoon size	1/- to 1/8½
Wire round—	
3/0 to 10 G.	1/6½ to 2/1½

with extras according to gauge.

AMERICAN IRON AND STEEL.

At Pittsburgh unless otherwise stated.

	Dols.
No. 2X foundry, Phila.	20.76
No. 2 foundry, Valley	17.25
No. 2 foundry, Birm.	16.00
Basic	18.76
Bessemer	19.26
Malleable	19.01
Grey forge	18.51
Ferro-mang. 80% d/d	100.00
O.-h. rails, h'y at mill	43.00
Bess billets	33.00
O.-h. billets	33.00
O.-h. sheet bars	34.00
Wire rods	44.00
	Cents.
Iron bars, Phila.	2.12
Steel bars	1.85
Tank plates	1.85
Beams, etc.	1.85
Skelp, grooved steel	1.85
Skelp, sheared steel	1.85
Steel hoops	2.20
Sheets, black, No. 24	2.85
Sheets, galv., No. 24	3.65
Sheets, blue an'l'd., 9 and 10	2.10
Wire nails	2.65
Plain wire	2.50
Barbed wire, galv.	3.35
Tinplate, 100 lb. box	$5.25

COKE (at ovens).

Welsh foundry	—
,, furnace	—
Durham and North.	
,, foundry	—
,, furnace	14/-
Other Districts, foundry	—
,, ,, furnace (basis)	12/- to 13/-

TINPLATES.

f.o.b. Bristol Channel porta.

I.C. Cokes	20×14	box	18/1½
,,	28×20	,,	36/3
,,	20×10	,,	—
,,	18¾×14	,,	—
C.W.	20×14	,,	17/-
,,	28×20	,,	—
,,	20×10	,,	—
,,	18¾×14	,,	—
Terneplates	28×20	—	per box basis f.o.b.

SWEDISH IRON.

Bars, hammered,	£17 10 0 to £18 10 0
Rolled Ord.	£15 0 0 to £15 10 0
Nail rods	£15 7 6 to £15 15 0
Keg. steel nom.	£33 to £35
Faggot steel nom.	£22 to £25
Blooms, according to quality	£8 to £12
Pig-iron	£5 15 0 to all f.o.b. Gothenburg.

TUBES AND FITTINGS.

Up to and incl. 6 in.

	Tubes.	*Fittings.*
Gas	67½%	45%
Water	63½%	40%
Steam	60%	35%
W.I. 10% extra.		

DAILY FLUCTUATIONS.

Standard Copper (cash).

	£ s. d.	
April 4 ..	61 17 6	No change
,, 5 ..	61 13 9	dec. 3/9
,, 10 ..	61 16 3	inc. 2/6
,, 11 ..	61 13 9	dec. 2/6

Electrolytic Copper.

	£ s. d.	
April 4 ..	66 10 0	No change
,, 5 ..	66 10 0	,, ,,
,, 10 ..	66 10 0	,, ,,
,, 11 ..	66 10 0	,, ,,

Standard Tin (cash).

	£ s. d.	
April 4 ..	238 10 0	dec. 25/-
,, 5 ..	237 5 0	,, 25/-
,, 10 ..	235 7 6	,, 37/6
,, 11 ..	230 12 6	dec. 95/-

Tin (English ingots).

	£ s. d.	
April 4 ..	243 15 0	dec. 25/-
,, 5 ..	242 10 0	,, 25/-
,, 10 ..	240 10 0	,, 40/-
,, 11 ..	235 10 0	dec. 100/-

Zinc Sheets (English)

	£ s. d.	
April 4 ..	33 10 0	No change
,, 5 ..	33 10 0	,, ,,
,, 10 ..	33 10 0	,, ,,
,, 11 ..	33 10 0	,, ,,

Spelter (ordinary).

	£ s. d.	
April 4 ..	24 18 9	No change
,, 5 ..	25 0 0	inc. 1/3
,, 10 ..	24 18 9	dec. 1/3
,, 11 ..	24 15 0	dec. 3/9

Lead (English).

	£ s. d.	
April 4 ..	21 10 0	No change
,, 5 ..	21 10 0	,, ,,
,, 10 ..	21 10 0	,, ,,
,, 11 ..	21 10 0	,, ,,

AVERAGE MONTHLY PRICES OF STEEL BOILER PLATES IN ENGLAND.

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1895 ..	5 15 0	5 15 0	5 12 6	5 12 6	5 15 0	5 17 6	5 15 0	5 17 6	6 0 0	6 0 0	6 2 6	6 0 0	5 16 10½
1896 ..	6 0 0	6 0 0	6 2 6	6 2 6	6 2 6	6 0 0	6 0 0	6 0 0	6 0 0	6 2 6	6 10 0	6 10 0	6 2 6
1897 ..	6 10 0	6 10 0	6 10 0	6 7 6	6 2 6	6 2 6	6 5 0	6 0 0	6 0 0	6 0 0	6 7 6	6 10 0	6 5 5
1898 ..	6 10 0	6 8 9	6 8 9	6 10 0	6 15 0	6 18 9	6 17 6	6 17 6	7 2 6	6 15 0	7 0 0	7 5 0	6 15 8½
1899 ..	7 5 0	8 0 0	8 2 6	8 2 6	8 5 0	8 5 0	8 12 6	8 12 6	8 15 0	8 15 0	9 2 6	9 5 0	8 17 8½
1900 ..	9 5 0	9 5 0	9 7 6	9 10 0	9 12 6	10 5 0	10 5 0	10 5 0	10 5 0	10 0 0	9 15 0	9 15 0	9 15 10
1901 ..	9 5 0	9 5 0	8 15 0	8 10 0	8 10 0	7 10 0	7 15 0	7 15 0	7 15 0	7 15 0	7 15 0	7 15 0	8 3 11
1902 ..	7 7 6	7 0 0	7 12 6	7 12 6	7 12 6	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 9 7
1903 ..	7 10 0	7 10 0	7 15 0	7 5 0	7 5 0	7 5 0	7 5 0	7 0 0	7 0 0	7 0 0	7 0 0	6 17 6	7 3 11½
1904 ..	6 12 6	6 15 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	6 18 11½
1905 ..	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 17 6	6 10 0	7 5 0	8 0 0	8 0 0	7 1 3
1906 ..	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	8 10 0	8 0 10
1907 ..	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 10 0	8 0 0	8 0 0	8 8 4
1908 ..	7 10 0	7 10 0	7 10 0	7 5 0	7 5 0	7 5 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	7 3 9
1909 ..	7 0 0	7 0 0	7 0 0	7 0 0	7 0 0	6 15 0	6 15 0	6 15 0	7 0 0	7 0 0	7 0 0	7 0 0	6 18 9
1910 ..	7 0 0	7 0 0	7 1 3	7 5 0	7 5 0	7 5 0	7 5 0	7 5 0	7 5 0	7 10 0	7 10 0	7 10 0	7 5 1
1911 ..	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 10 0	7 14 0	7 10 4
1912 ..	7 18 9	8 0 0	8 0 0	8 7 6	8 10 0	8 10 0	8 10 0	8 15 0	8 16 3	9 0 0	9 2 0	9 5 0	8 11 2½
1913 ..	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	9 5 0	8 19 0	8 15 0	8 5 0	7 15 0	7 15 0	8 17 0
1914 ..	7 15 0	7 15 0	7 15 0	7 13 9	7 10 6	7 5 0	7 0 0	8 0 0	8 2 6	8 5 0	8 5 0	8 5 0	7 15 11½
1915 ..	8 14 0	9 10 0	9 17 6	10 10 0	10 10 0	11 0 0	11 0 0	11 0 0	11 0 0	11 4 0	12 0 0	13 0 0	10 16 5½
1916 ..	13 0 0	13 0 0	13 0 0	12 15 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 12 11
1917 ..	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0
1918 ..	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0	12 10 0
1919 ..	13 0 0	15 0 0	15 0 0	15 0 0	19 5 0	19 17 6	21 0 0	21 10 0	21 10 0	21 10 0	21 15 0	23 10 0	18 9 9
1920 ..	26 0 0	28 0 0	28 5 0	28 10 0	29 5 0	30 0 0	30 0 0	30 0 0	30 10 0	31 0 0	31 0 0	31 0 0	29 9 2
1921 ..	30 5 0	29 0 0	25 0 0	25 0 0	25 0 0	23 0 0	21 0 0	20 10 0	19 0 0	17 10 0	16 0 0	14 16 0	22 1 9
1922 ..	14 10 0	14 10 0	14 10 0	14 10 0	14 10 0	13 1 8	13 10 0	12 15 0	12 10 0	12 10 0	12 10 0	12 6 0	13 10 9
1923 ..	12 8 9	13 6 0	14 0 0	14 0 0	14 0 0	14 0 0	13 12 6	13 0 0	13 0 0	13 0 0	13 0 0	13 10 0	13 9 1½
1924 ..	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	13 10 0	14 0 0	14 0 0	13 11 0	13 5 0	13 5 0	13 10 11
1925 ..	13 5 0	13 5 0	13 5 0	13 1 0	12 15 0	12 15 0	12 15 0	12 15 0	12 7 6	11 14 0	11 10 0	11 10 0	12 11 5½
1926 ..	11 10 0	11 10 0	11 10 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 5 0	11 6 3
1927 ..	11 5 0	11 5 0	11 5 0	11 5 0	11 2 6	11 0 0	11 0 0	11 0 0	10 16 0	10 10 0	10 10 0	10 10 0	10 19 0½
1928 ..	10 10 0	10 10 0	10 10 0	10 10 0	—	—	—	—	—	—	—	—	—

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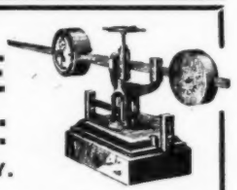

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